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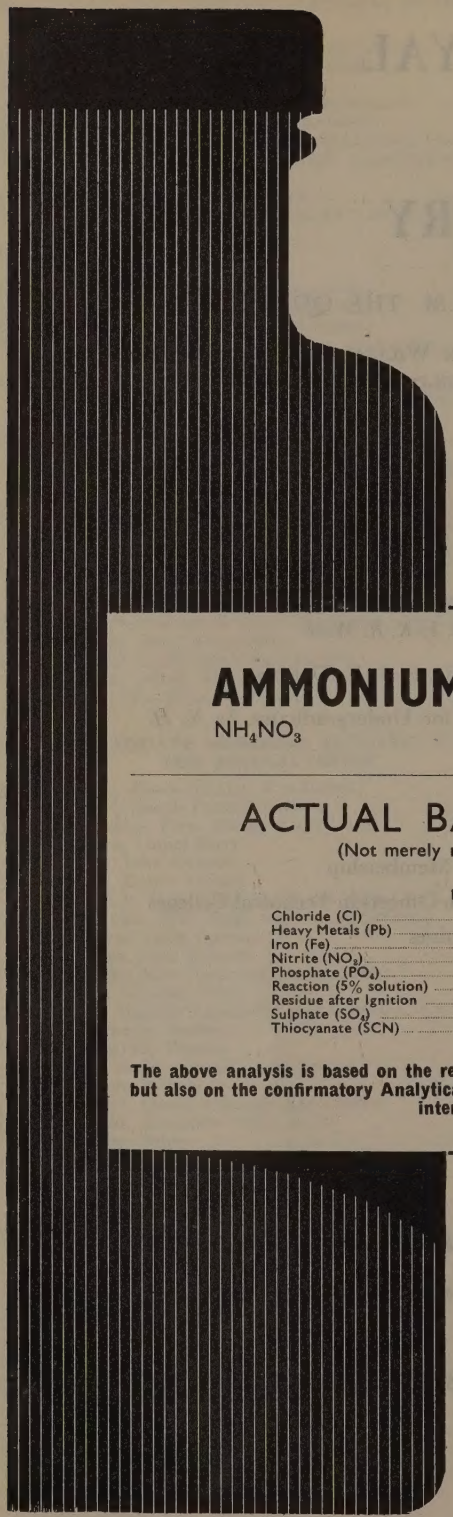

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SIR WILLIAM ROBERT GROVE (1811-1896) AND THE ORIGINS OF THE FUEL CELL

By K. R. WEBB, B.SC., PH.D., F.R.I.C.
Department of Chemistry, University of Southampton

Since about 1945 there has been a great revival of interest in so-called fuel cells, which are essentially devices by which the chemical energy of a fuel such as hydrogen, hydrocarbons and so on can be converted directly into electrical energy by an electrochemical oxidation process. In a recent article[1] we read: 'When burned in a steam turbine or automotive-type engine, 60-85 per cent of the energy in the fuels they run on is lost as waste heat. By converting the energy of a fuel directly to electricity in a fuel cell without using a heat engine, this waste is reduced to 20-30 per cent. Other possible advantages of the fuel cell are reduced atmospheric pollution from exhaust gases and less noise.' In view of all this, it is interesting to take a brief look at the life and work of the man who seems to have been the first worker in this field—(Sir) William Robert Grove, born 150 years ago—on 11 July, 1811—in Swansea. His career is remarkable not only for his important scientific work, but also because he was, professionally, a lawyer and ultimately a Judge. Indeed, we have here a situation rather the mirror-image of that of the musician Borodin, who was, professionally, a university teacher of chemistry (with a fair amount of scientific work in print to his credit), but whose contributions to music are much more noteworthy.

William Robert Grove was the only son of John Grove, a magistrate, and deputy lieutenant for Glamorgan, and his wife, *née* Anne Bevan.[2] After being educated by private tutors he went up to Brasenose College, Oxford, in 1829 and took his B.A. in 1832. In 1835 he was awarded the degree of M.A., and was called to the Bar on 23 November, 1835, at Lincoln's Inn, of which he had been admitted a student four years earlier. During the next few years, it seems that the state of Grove's health was such that he could not become fully active in the law and was, therefore, free to spend a good deal of time on what was his natural bent—scientific research. Indeed, almost all his really important scientific work was published in the decade 1839–49, although there were minor contributions long after that.

In 1839, there appeared in the *Philosophical Magazine* a paper by Grove entitled 'On a New Voltaic Combination'; this dealt with what was afterwards often called his nitric acid battery, and should *not* be confused with his fuel cell work, since it was simply the production of a conventional voltaic battery of, however, considerable power and robustness in which zinc in dilute sulphuric acid, separated by a porous pot from platinum in concentrated nitric acid, formed the active elements. An account of the prototype of this battery can be read in Grove's collected scientific papers;[3] it became very popular (the Grove cell) and according to one account:[4] 'at one of his lectures at the [London] Institution he anticipated the electric lighting of today by illuminating the theatre with incandescent electric lamps, the filaments being of platinum and the current supplied by a battery of his nitric acid cells.' This was presumably during Grove's period as Professor of Experimental Philosophy in the London Institution, Finsbury Circus (1840–47), and, if so, was well before the work of Swan and Edison (1879) on filament electric lighting.

It was also in 1839, however, that Grove published, again in the *Philosophical Magazine*,[5] a short note on the 'Synthesis of Water by Voltaic Action,' containing observations which were the beginning of his work on the fuel cell. For the purposes of the present account it is more convenient to quote from a later paper[6] 'On the Gas Voltaic Battery' (as he always called the device), which was read before the Royal Society on 11 May, 1843, and which shows the fundamental principle more fully developed. The following is Grove's account: 'In the *Philosophical Magazine* for December 1842 I have published an account of a voltaic battery in which the active ingredients were gases, and by which the decomposition of water was effected by means of its composition. The battery described in that paper' he continues, 'consisted of a series of tubes containing strips of platinum foil covered with a pulverulent deposit of the same metal; the platinum passed through the upper parts of the tubes, which were closed with cement, the lower extremities were open; they were arranged in pairs in separate vessels of dilute sulphuric acid, and of each pair one tube was charged with oxygen, the other with hydrogen gas, in quantities such as would allow the platinum to touch the dilute acid; the platinum in the oxygen of one pair was metallically connected with the platinum in the hydrogen of the next, and a voltaic series of 50 pairs was thus formed. With this battery the following effects were produced:—

(1) A shock was given which could be felt by five persons joining hands.

(2) The needle of a moderately sensitive galvanometer was whirled round and remained permanently deflected 60°.

(3) A gold-leaf electroscope was notably affected.

(4) A brilliant spark visible in broad daylight was given between charcoal points.

(5) Iodide of potassium, hydrochloric acid, and water acidulated with sulphuric acid were severally decomposed; the gas from the decomposed water was collected and detonated. The gases were evolved in the direction which the chemical theory would indicate, the hydrogen travelling in one direction throughout the circuit, and the oxygen in the reverse.'

A picture of the experimental set-up is given in Grove's book, *The Correlation of Physical Forces*.[7]

What essentially was happening in each of these gas cells was that the hydrogen was being electrochemically oxidized by the oxygen to water. At the oxygen electrode, the platinized platinum catalysed the reaction:

$$O_2 + 2H_2O + 4e \longrightarrow 4OH^-$$

These hydroxyl ions then reacted in the electrolyte to form water with hydrogen ions, produced at the hydrogen electrode by the following reaction, again catalysed by the platinized platinum:

$$2H_2 \longrightarrow 4H \text{ (adsorbed)} \longrightarrow 4H^+ + 4e$$

The electrons, flowing through the external circuit when it was completed, constituted the observed electric current.

In a later paper,[8] a more elaborate form of the gas voltaic battery was given. An important feature of this arrangement was that the oxygen tubes were dispensed with and replaced simply by platinized platinum strips partially immersed in the electrolyte (dilute H_2SO_4) and otherwise exposed to 'the atmospheric air [this] supplying an inexhaustible source of oxygen.' The hydrogen required was generated from dilute sulphuric acid and zinc.

Grove also tested the voltaic effects of other gaseous systems besides the oxygen–hydrogen one, and found, for instance, that a rather feeble effect could be obtained from oxygen and ethylene; however, oxygen and carbon monoxide produced 'notable effects,' and chlorine and hydrogen 'gave very powerful effects.' Indeed, only *two* chlorine–hydrogen cells in series were needed to give enough e.m.f. to decompose water, with platinum electrodes, and this combination formed[9] 'the most powerful gas battery,' but its action was not very constant over a period of time, probably because of direct interaction of the chlorine with the aqueous electrolyte.

Grove does not seem to have envisaged his gas voltaic battery as a practical producer of electrical energy, except perhaps for the electric telegraph. He indicates that a continuous intensity of e.m.f. can be produced this way, but that the amount of electricity generated (anyhow, with the simple laboratory models which he described) would be small. In a way, his device might, however, be regarded as the forerunner of the so-called 'secondary batteries' (*e.g.* accumulators) used to store electricity, the hydrogen and oxygen required being generated in the first instance electrolytically. Indeed, it seems possible that modern fuel cells of a similar type, but with much improved electrodes, might now be used as electrical storage mechanisms in just this kind of way. A recently-described fuel cell[1] 'can operate with either alkaline or acid electrolytes. When run on hydrogen and oxygen at a pressure of 3 lb/in^2, current densities of 70 A/ft^2 can readily be obtained with both types of electrolyte at room temperature. If air is substituted for oxygen, there is little loss in performance. As the cell warms up to 60°C, the output is doubled. Power per cu. ft is 3–5 kW.'

Mention has already been made of Grove's period as Professor of Experimental Philosophy at the London Institution. During his tenure of this office, he published a short but very important book, entitled *The Correlation of Physical Forces* (1846). This was a fuller development of a professorial lecture 'On the Progress of Science since the Foundation of the London Institution,' delivered in January, 1842. In this book, which passed through six editions, Grove anticipated Helmholtz's exposition of the principle of conservation of energy which appeared in 1847. The fundamental idea[4] was 'that each of the forces of nature—light, heat, electricity, etc.—is definitely and equivalently convertible into any other, and that where experiment does not give the equivalent, it is because the initial force has been dissipated, not lost, by conversion into other unrecognised forces.' Of Grove's and Helmholtz's work, Professor A. Gray[10] later wrote: 'These two remarkable essays may be said to form the starting-point of the modern science of energetics, of which the experimental foundation was even then being overhauled and laid still more deeply and stably by Joule.'

It is impossible in a short article to discuss fully all Grove's contributions to science. The interested reader is referred to Grove's own collection of them.[3] Much of the work deals with electrical and related phenomena, but there are also papers on optical and astronomical matters. It should be mentioned that Grove's scientific work was widely appreciated by his contemporaries; he became a Fellow of the Royal Society on 26 November, 1840, was an original Fellow of the Chemical Society (1841) and was elected a Vice-President of the Royal Institution in 1844. Later, he was made D.C.L. (Oxford) in 1875 and LL.D. (Cambridge) in 1879.

I will conclude by saying a little more about Grove's later life in the law. As his health improved, his legal work increasingly expanded, and his reputation as a scientist often brought him briefs in patent cases. He took silk, becoming a Q.C. in 1853, and in 1856 he appeared for the defence of the poisoner, William Palmer, in the great Rugeley murder case. In September, 1864, he was appointed a member of the Royal Commission then set up to inquire into the law of patents.

About seven years later (November, 1871) Grove was appointed a Judge in the Court of Common Pleas; he was knighted in 1872, and in 1880 was transferred to the Queen's Bench Division. One account[2] says: 'He proved an efficient judge, but, as he was not specially assigned to the hearing of patent cases, it may be doubted whether his services to suitors were such as to compensate for his withdrawal from scientific investigation.' He retired from the Bench in September, 1887, was made a member of the Privy Council, and returned joyfully and energetically to his scientific studies. But his powers were waning and, after a slow decline, he died at his house in Harley Street, London, on 1 August, 1896, aged 85. Professor A. Gray, in an obituary notice for *Nature*,[10] said of him: 'It has been given to few to witness, as did Sir William Grove, almost all the scientific progress of the nineteenth century, and it must have well rewarded his scientific spirit to see the younger generation enter into the labours of the founders of the theory of energy with so much eagerness and so great a promise of fruitful achievement.'

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FIBRES FROM POLYPROPYLENE*

By A. B. THOMPSON, B.A.

Imperial Chemical Industries Ltd, Fibres Division, Harrogate

Polypropylene now promises to be of great importance in chemical industry. And yet throughout the great rise in importance of polyethylene no useful polymers at all were made from propylene. High molecular weights were reported by Fontana,[1] using an $AlBr_3$/HBr catalyst system, but the products were all sterically irregular and highly branched, so that they were either viscous oils or soft amorphous solids of little technical interest.

In 1954, however, Natta[2] discovered a modified Ziegler catalyst based on titanium trichloride and triethyl aluminium, which not only polymerized propylene to a high molecular weight, but so directed the polymerization that the bulk of the product was of sufficient steric regularity to crystallize. Compared with polythene this new material has a higher softening point, a higher rigidity which is less sharply reduced by rising temperature, and a lower density.

These properties of polypropylene, together with the low cost of manufacture from readily available supplies of propylene, first made this new polymer of major interest as a moulding plastic. Six years after the first discovery, plants are now in operation in many countries. In the U.S.A. alone production capacity rose from about 10,000 tons per year in 1958 to about 60,000 tons in 1960 and is expected to reach 250,000 tons shared between at least eight major producers by the end of 1962. The Plastics Division of I.C.I. is operating an 11,000 ton/year plant at its Wilton Works, with an expansion to at least 33,000 ton/year envisaged in the next few years. Polypropylene is also suitable for the production of melt-extruded film, monofilament and fibre, and these applications are being developed. The Fibres Division of I.C.I. has plans for manufacture and has set up pilot plants, again at its Wilton Works.

Polypropylene fibres are of low density, high strength and high durability. They are also expected to fall in the price range between the more expensive polyamides, polyesters and finer wools on the one hand, and rayons, cottons and bast fibres on the other. This combination of properties and price leads us to expect that polypropylene will find wide applications in fibre markets.

In its current manufacture, highly purified monomer is contacted with a suspension of catalyst in a suitable inert diluent. The heterogeneous catalyst is the key to the successful operation of the process, controlling the steric regularity or tacticity of the product and the polymerization rate. The molecular weight is controlled by suitable additives and choice of polymerization temperature, as has been described in the literature[3,4].

Ciampa[5] has given the following relation between intrinsic viscosity and number-average molecular weight:

$$\text{I.V.} = M_n \times 2{\cdot}5 \,.\, 10^{-5}$$

The number-average molecular weight was determined by osmotic pressure measurements and the

* Paper given at the Symposium on 'Chemicals from Petroleum' on 20 April, 1961, at Southampton.

intrinsic viscosity was determined in tetralin at 135°C. There is some evidence that this single linear equation holds irrespective of tacticity or degradation. We measure the intrinsic viscosity of polypropylene fibres in decalin at 135°C, obtaining values about 1·16 times higher than those obtained in tetralin, and they usually lie between 1·0 and 2·0 *dl*/g. This corresponds to number-average molecular weights between 40,000 and 80,000. The measurement of solution viscosity is, however, very tedious because hot solvents must be used and precautions must be taken against oxidative degradation. We place more importance on melt-extrusion viscosity, which is easier to measure and more directly related to the melt-spinning of fibres. This is measured in a modified polythene grader, the rate of extrusion through a die being measured at constant temperature and pressure. Our standard die is of diameter 0·082 in and length 5/16 in, the temperature is 190°C and the standard pressure is achieved by piston loadings of 2 kg or 10 kg, chosen according to the molecular-weight range, and applied over 0·71 cm^2 of polymer feeding the extrusion die. Care must be taken to avoid viscosity effects in the polymer chamber above the die, so we use the final piston velocity at the end of the stroke to calculate the extrusion rate when the pressure is applied at the die itself. The measurement is expressed as a melt flow index in units of grams per 10 minutes, and the melt flow indices and I.Vs of a range of I.C.I. polymers and fibres are related as shown in Fig. 1. The intrinsic solution

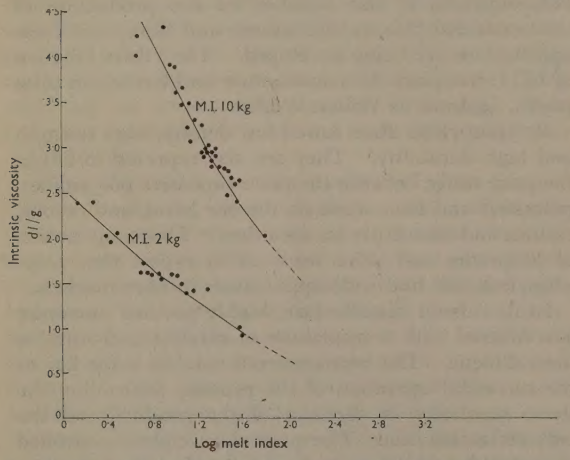

FIG. 1. Intrinsic Viscosity vs. Melt Flow Index for Polypropylene

viscosity and the melt-extrusion viscosity are related to different mean molecular weights, and may depend differently on tacticity. The correlations in Fig. 1, therefore, only refer to a particular but typical range of polymers and fibres.

Molecular-weight distribution and tacticity are also important factors behind the molecular structure and mechanical properties of fibres, but until they can be measured with confidence, many features of fibre behaviour will remain obscure. Because atactic polymers cannot crystallize, the degree of crystallinity of a polymer has often been used as a rough measure of its tacticity. Material that remains amorphous even after careful annealing may be designated 100 per cent atactic, but there is no other fixed point at 100 per cent isotacticity, since even if we could isolate such material, the degree of crystallinity it reached would depend on other factors, such as molecular-weight distribution and thermal history. Crystallinity is no more than a general guide to tacticity. Nor can solvent-extraction methods give quantitative measures of either tacticity or molecular-weight distribution, although this has often been attempted.[6] Diethyl ether appears to extract wholly uncrystallizable atactic material, but in polymers normally used for fibres the proportion is no more than 0·5 per cent, and the remaining polymer is not wholly isotactic. Other solvents extract further fractions of both low molecular weight and moderate tacticity. In boiling heptane, for example, about 5 or 6 per cent of polymers normally used for fibres is extracted; but this is not a measure of tacticity only, for the figure rises sharply with degradation and is closely correlated with I.V. Fractionation, by extractions at rising temperatures in petrol ether,[7] gives a cumulative extracted weight fraction rising smoothly with temperature, but both the maximum attainable crystallinity and the intrinsic viscosity of the fractions vary in a complicated way, reaching minima at quite different temperatures. It is evident that molecular weight and tacticity are both important factors in the extraction.

In order to search for a better basis of measurement it is necessary to define tacticity with more precision. Ward[8] has adopted the definition that when both the neighbours of a monomer unit are identically substituted, that unit is in an isotactic environment. Then provided that the chain configuration is helical, as in the crystal lattice, an isotactic monomer unit will show specific molecular vibrations recognizable in the infra-red spectrum. These characteristic infra-red absorptions will not indicate either crystallinity or tacticity *per se*, for helical isotactic configurations may or may not be in crystalline neighbourhoods, and isotactic units may or may not be in helical configurations. But this method does allow us to measure something precise: the density of isotactic units in the helical configuration. By comparing the spectra of normal and deuterated polypropylenes, Ward[8] has made some infra-red band assignments which extend earlier work (*e.g.* that of Peraldo[9] and Brader[10]) and suggest that bands at 1167, 997 and 841 cm^{-1} are characteristic of the helical isotactic arrangement. Luongo[11] has also chosen a set of bands as characteristic of isotactic polymer, and two of these, at 995 and 842 cm^{-1}, appear to be identical with two chosen by Ward. Further evidence is needed

—and it is now being sought through N.M.R. studies—to show what molecular rotations occur at different temperatures and how far this measure of helical configurations may be used as a direct measure of isotactic groupings.

The determination of melting points and crystallinities also presents difficulty because despite their technological importance neither can be at all clearly defined. The problem is illustrated by the data of Dole *et al.*[12] for polythene. The degree of crystallinity, its reduction with rising temperature and the temperature at which crystallinity finally disappears can all be estimated by different techniques, but there is no close agreement between the results. Nevertheless there is a definite contrast between polythene and two other fibre-forming polymers, nylon 66 and polyethylene terephthalate. In these polymers drawn samples actually increase in crystallinity with rising temperature.[13,14,15] Not much information is yet available for polypropylene but Fig. 2 gives some data derived from X-ray studies.[17,18]

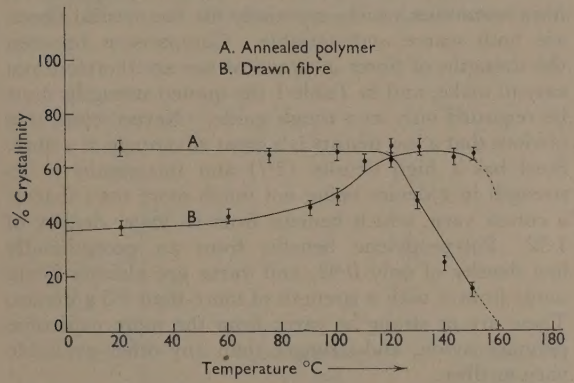

FIG. 2. Crystallinity vs. Temperature for Polypropylene

The melting range of annealed polypropylene is wide, but drawn samples do show an increase of crystallinity as the temperature rises. This is of significance in some textile setting operations, because the drawn fibres are only moderately crystallized, and when they are heat-set the increased crystallinity locks the structure more firmly in its desired shape, reinforcing the setting effect due to stress relaxation. The temperature at which crystallinity disappears is estimated by these various techniques at between 165 and 175°C. Another method of approach is to determine the temperature at which the tensile strength of a filament becomes zero, this being taken, in the absence of cross-linking, as the melting point. There is a well-known thermodynamic relation between melting point and hydrostatic stress, and in anisotropic materials there is a parallel but much more sensitive relation, described by Gee,[16] between melting point and tensile stress. The effect in polypropylene fibres is illustrated in Fig. 3. Strength disappears under zero stress at around 165°C, and under applied stress this melting point can rise to at least 200°C. Above

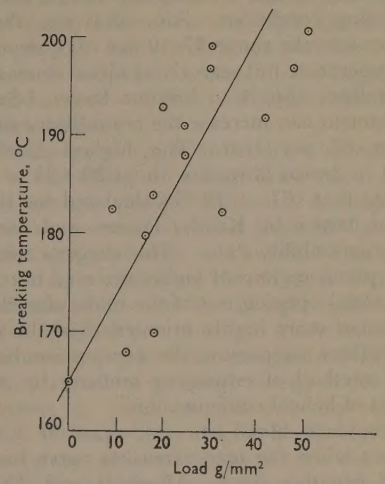

FIG. 3. Melt Point vs. Stress for Polypropylene

about 165°C the polymer can be handled as a viscous fluid, provided that high stresses are avoided. It is possible that the irregular extrusion instability effect, known as melt fracture or cold extrusion, observed when the shear stresses in a molten polymer become high, may be connected with this behaviour. Below about 165°C, and down to the transition temperature range at −25°C to 0°C, polypropylene crystallizes.

The molecules of polypropylene are known from X-ray analysis to be helically arranged in the crystal lattice,[19] and there is evidence of two or more crystalline forms under different conditions of molecular weight and temperature of crystallization. There is also a complicated range of spherulites which grow under different experimental conditions.[20] The importance of these different structures in determining mechanical properties is not clear, especially in highly oriented fibres that are not spherulitic. It is interesting, however, to examine the crystallinities reached at each stage of the fibre-making process. Because polypropylene can only be dissolved with difficulty in a restricted range of solvents above 100°C, spinning from solution is unattractive, but it is sufficiently thermally stable to be formed into fibres by melt-spinning. After spinning the fibres are drawn, introducing a high degree of molecular orientation, a low extensibility and good elastic recovery. Finally, heat treatments are used to alter the physical properties of the fibre, through controlled relaxation and crystallization.

Polymer for fibres usually has a crystallinity of about 50 per cent, which can be increased to 68 per cent by careful heat treatment.[17] The spun filaments wound up after extrusion, stretching and cooling develop

a crystallinity of about 33 per cent, and are optically birefringent, showing that there is some molecular orientation, the extent of which depends on the extrusion and winding conditions. After drawing, the crystallinity rises into the range 37–48 per cent, depending on draw temperature but scarcely at all on draw ratio, and the crystallites appear to become larger. Subsequent heat treatment can increase the crystallinity still further to about 68 per cent. The highest birefringences observed in drawn fibres are about $30 - 35 \times 10^{-3}$, not as high as that (67×10^{-3}) calculated for the helical crystalline lattice by Keedy, Powers and Stein[21] from atomic polarizability data. This suggests that even in the amorphous regions of highly oriented fibres there is no substantial opening out of the molecular chains to a configuration more highly oriented than the helices in the crystallites, supporting the assumption behind the infra-red method of estimating tacticity by measuring the extent of helical configurations.

Polypropylene fibres can cold-draw at a shoulder. This arises when the load/extension curve has a finite range of negative slope. Marshall and Thompson[22] showed how this could occur adiabatically, and more recently Vincent[23] has shown that some polymers have stress/strain curves which provide a negative sloping load/extension curve even isothermally. Polypropylene 'necks' when the diameter is high, that is under fairly adiabatic conditions, but only stretches uniformly when the filament diameter is low and the conditions are almost isothermal. A wide variety of types of fibre can be made from a single grade of polymer by varying the conditions of spinning, drawing and heat treatment, as illustrated by Fig. 4. In most fibre applications we are interested mainly in the breaking load for a given weight. Thus strengths are usually given, not in terms of kg/mm², but in terms of grams/denier. The denier is a traditional textile unit of linear density—the weight in grams of 9,000 metres length. The strength in grams per denier is the strength in kg/mm² divided by nine times the density. It is not often possible to make filaments in bulk with the maximum strength attainable experimentally, nor are fibres used alone, but always in cords,

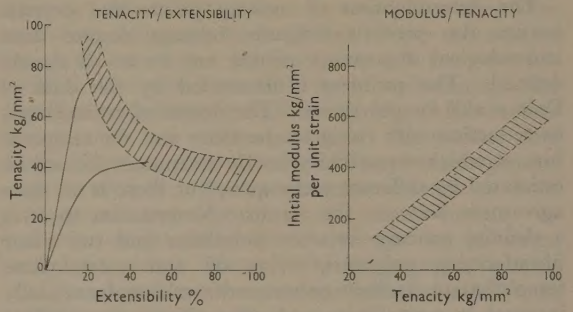

FIG. 4. Simple Tensile Properties of Polypropylene Fibres

ropes or fabrics, and the properties of single fibres must be supplemented by data on the properties of fibre assemblies which, especially for the natural fibres, are both scarce and variable. Comparisons between the strengths of fibres in practical use are therefore not easy to make, and in Table 1 the quoted strengths must be regarded only as a rough guide. Nevertheless, it is obvious that a low density is a great advantage in a fibre. Steel has a high density (7·7) and this results in its strength in g/denier being not much more than that of a cotton yarn, which benefits from its lower density of 1·52. Polypropylene benefits from an exceptionally low density of only 0·92, and yarns are already being made from it with a strength of more than 8·5 g/denier. These are as strong as yarns from the more expensive polymer nylon, and stronger than any other available yarn or fibre.

Polypropylene fibres are as strong wet as dry, and they have a modulus of elasticity within the range 60–80

TABLE I

SOME COMPARATIVE MECHANICAL PROPERTIES OF HIGH-STRENGTH YARNS

Fibre	Specific gravity	Moisture uptake %	Yarn tenacity (grams per denier)	Initial modulus of fibre elasticity (grams per denier per unit strain)	Resistance to abrasion	Melting point °C	Remarks
Steel	7·7	0	3·5	280	Good	~1450	Minerals
Glass	2·56	0	6·0 to 7·0	307	Poor	~ 800	Minerals
Manila	1·48	8·0	around 4	250	Fair	140	Cellulosics
Cotton	1·52	8·5	„ 3·0	55	Fair	150	Decompose rather than melt
Flax	1·50	12·0	„ 4·0	200	Fair	140	Tenacities very approximate
Rayon (Tenasco)	1·52	13·0	3·5 to 5·5	75–175	Fair	180–205	Regenerated Cellulosic
'Terylene'	1·38	0·4	6·0 to 7·5	130	Very good	264	Polyester
Nylon	1·14	4·2	7·0 to 8·8	45	Excellent	264	Polyamide
High-density Polythene	0·95	0	4·5 to 6·0	30	Good	135	Polyolefins
Polypropylene	0·92	0	8·5 to 9·0	60–80	Good	165	Polyolefins

g/denier per unit strain; so they are neither too elastic nor too stiff for convenience (the modulus of nylon is rather lower at about 45, and that of steel is much higher at about 280). The extensibility of these

TABLE II

POLYPROPYLENE FIBRE—IMPACT STRENGTHS IN ARBITRARY UNITS

Temperature °C	Highly oriented fibre	Essentially unoriented fibre
+22	5·1	7·1
+10	4·9	1·7
0	5·5	0·2
−10	4·7	0·5
−30	5·1	0·5
−50	5·1	0·6
−70	5·5	0·6
−100	5·2	0·6

polypropylene yarns is 17–20 per cent, compared with 10–15 per cent for nylon, and only up to 8 per cent for steel. They can therefore absorb a large amount of energy under shock loading. Impact strengths measured on a simple pendulum tester are given in Table II. Though the impact strength of a fibre of low orientation is at first high, because of its high extensibility, it decreases rapidly below room temperature. On the other hand no reduction is seen in the highly drawn fibre even down to −100°C, well below the transition temperature range.

There is always a danger in making filaments of high tenacity by stretching to a high draw ratio, since the transverse strength can be reduced. A simple rough measure of transverse weakness is given by the strengths of knotted single filaments, and we find that although the knot strength ceases to rise, it does not actually begin to lessen even when the straight tensile strength has reached 10 g/denier. Strength in the sense of resistance to abrasion is probably connected with transverse strength and an ability to absorb energy of deformation. Polypropylene is good, second only to nylon and 'Terylene.' Perhaps surprisingly, however, the life of a polypropylene filament subjected to the abrading action of a rotating grind-stone increases as the filament

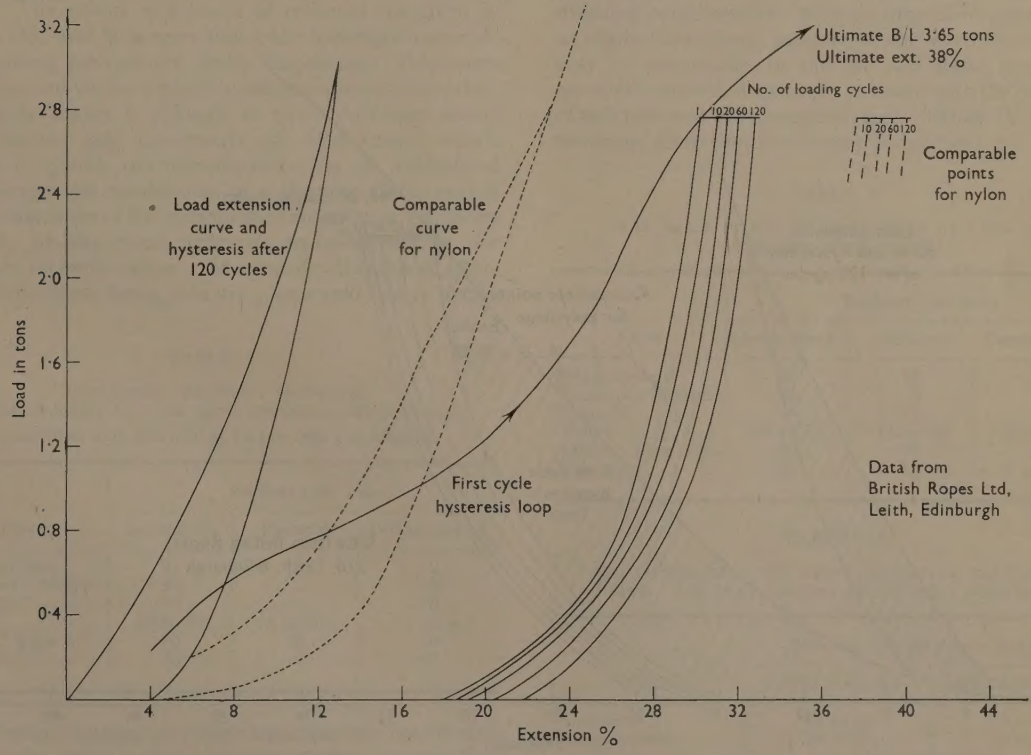

FIG. 5a. Tensile Properties of $1\frac{3}{4}$ in-circumference 'Terylene' Rope

diameter is reduced. Most practical abrading conditions are more complicated than this, involving flexing and rupture of the fibres due to snagging, as well as pure abrasive attrition. Where flexing and attrition are more important, fine filaments should be better, but where snagging and accidental damage are important thicker filaments may show some advantage.

Steel is pre-eminent for strength at very high temperatures, and the cellulosic fibres show little reduction of strength up to the temperature at which they begin to decompose; on the other hand, fibres which melt suffer a fairly steady loss of strength down to zero at the melting point. Because of their relatively low melting point, high-strength polypropylene fibres are therefore of interest primarily for articles used at atmospheric temperatures, such as ropes, nets and some industrial fabrics, rather than in articles used at high temperatures, such as tyres or belting. Thus the high strength, low density and high durability of polypropylene make it particularly suitable for use in ropes, twines, nets and fabrics used at atmospheric temperatures. Some data for ropes are given in Figs 5*a* and 5*b*.[24] Nylon and 'Terylene' show very similar creep and hysteresis properties, although the nylon rope has a rather higher strength and the 'Terylene' rope a higher modulus. Natural bast-fibre ropes show less creep, but are weaker and break under repeated loading up to three-quarters of the initial breaking load long before 100 cycles. Polypropylene behaves very similarly to nylon and 'Terylene' under the repeated loading test for 120 cycles, and its extensibility and modulus lie between those of the other two. Its breaking load is rather lower, but its density is also much lower, so that the rope is much lighter and its strength in terms of g/denier is high. Polythene, on the other hand, has a still lower breaking load without a corresponding density advantage and only survives some 40 loading cycles before breaking.

Fibres must also retain their strength after exposure to heat, light and various chemical reagents. In its degradation reactions polypropylene does not behave as a saturated hydrocarbon. The activation energy of its thermal degradation is lower than usual for a saturated hydrocarbon (*ca* 35 instead of >60 kcal/mole) and it is quite sensitive to radiation, although its absorption in the visible and ultra-violet is low. It is generally supposed that polypropylene is sensitive to thermally accelerated and photosensitized breakdown of hydroperoxide groups produced by oxidation at the tertiary carbon atoms in the propylene residues. By the addition of antioxidants and radiation absorbers, however, its stability can be made adequate for most fibre uses. There is already a considerable patent

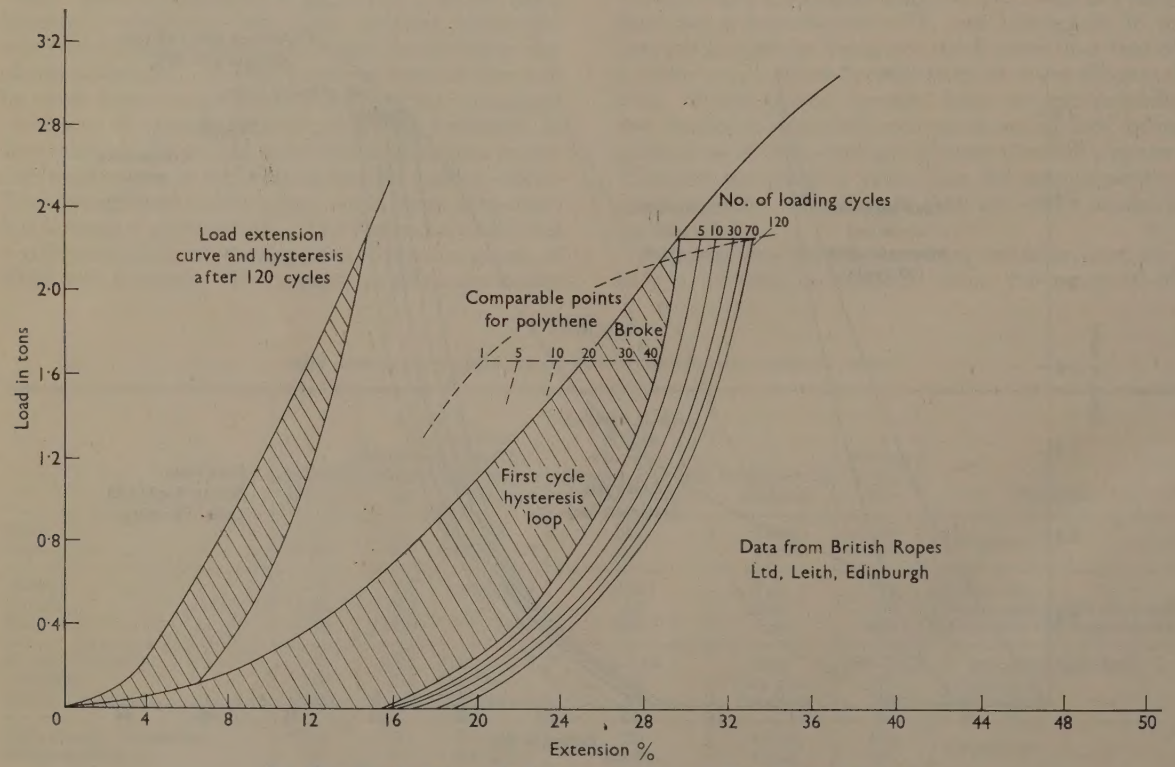

FIG. 5b. Tensile Properties of 1¾ in-circumference Polypropylene Rope

TABLE III

RESISTANCE OF 100 PER CENT POLYPROPYLENE YARNS TO CHEMICALS

Reagent	Temp. °C	Tested for 7 days				
		Change in wt per cent	Change in den per cent	Change in B/L per cent	Change in ten. per cent	Change in ext. per cent
Control	70	Nil	—	—	—	—
H_2SO_4 50 per cent w/w	„	−0·2	−13	−12	+2	−4
H_3PO_4 conc.	„	−0·2	−4	−6	−4	−4
HNO_3 20 per cent w/w	„	Nil	−6	+2	+8	−8
HCl conc.	„	−0·2	−3	−4	−1	—
NaOH 20 per cent w/w	„	−0·3	+1	−3	−4	−8
m-Cresol	„	−0·8	+2	+2	+1	−5
Benzene	„	−1·25	+7	−1	−8	+23
Fuel Oil		+0·7	−4	−13	−9	−8
H_2O_2 10 per cent w/w		−1·16	Too weak to test			
H_2O_2 10 per cent w/w	30	−0·1	−6	−20	−17	−2
Carbon tetrachloride	50	−1·0	+10	+2	−7	+21
Trichloroethylene	50	−1·07	−3	−4	−1	−5
Sodium hypochlorite 10 g/l	„	−1·1	+1	+13	+12	+2
Boiling Solvents		Tested for 4 hours				
Benzene	boil	−2·06	+25	−5	−24	+75
Trichloroethylene	boil	−16·8	Heavy shrinkage—no tests			
Carbon tetrachloride	boil	−3·9	+52	Heavy shrinkage—no tests		
m-Cresol	100	−0·8	+46	+26	−14	+102

literature on stabilizing additives, and further advances may be expected. Otherwise, polypropylene is fairly inert. The effects of a range of reagents are given in Table III, and it is seen that only hydrogen peroxide and boiling solvents are really damaging. This inertness, coupled with a negligibly small moisture absorption, inevitably makes it difficult to dye. Although many modifications and treatments are now known which render it dyeable, no manufacturer has yet announced the commercial production of a dyeable fibre, and it seems that none of the various modifications is yet cheap enough, or has given adequate technical effects, for commercial exploitation. Meanwhile all coloured polypropylene fibres being sold are pigmented before extrusion.

TABLE IV

SINGLE-FIBRE RECOVERY PROPERTIES AFTER HOLDING AT 2 PER CENT EXTENSION FOR 30 SECONDS

(extension and recovery at 10 per cent per minute)

Fibre	Recovery per cent		
	Immediate	Delayed	Permanent set
Polypropylene	91	9	0
'Terylene,' N type	95	5	0
Nylon 66	88	12	0
'Tricel'	84 to 95	5 to 16	−2 to +2
'Orlon,' Type 81	60	24	16
Viscose	46	11	43

For many outlets, very high tenacities are not needed but creep, stress relaxation and elastic recovery are important for dimensional stability, resilience and creasing performance. In textiles, fabric structure and finishing processes both play an important part, as well as single-fibre elastic properties, and even these are not easy to summarize in one or two basic parameters, especially since they can vary so much with the conditions of polymer and fibre manufacture. Tables IV–VI give, however, some simple recovery properties.

TABLE V

AS IN TABLE IV BUT FILAMENTS HELD AT 2 PER CENT EXTENSION FOR 3 MINUTES

Fibre	Recovery per cent		
	Immediate	Delayed	Permanent set
Polypropylene	82	18	0
'Terylene,' N type	91	9	0
Nylon 66	79	21	0
'Tricel'	63 to 73	11 to 19	about 16
'Orlon,' Type 81	50	23	27
Viscose	34	29	37 variable

TABLE VI

SINGLE-FIBRE RECOVERY PROPERTIES AFTER HOLDING UNDER 1 PER CENT BENDING STRAIN FOR 6 MINUTES

Fibre	Per cent recovery from strain	
	After 1 second	After 100 seconds
'Terylene'	83 to 86	93 to 96
Polypropylene	40 to 50	90 to 94

The recovery of polypropylene after rapid loading and unloading is good, but after holding under strain for a long time it becomes slow. The elastic work done initially in stretching is, therefore, largely lost; there is only a small potential energy available for recovery, and so the fibre is fairly easily retained in its deformed shape. Some implications of this behaviour are illustrated in Tables VII and VIII; in a carpet pile, where

TABLE VII

TUFTED CARPET PILE RECOVERY PROPERTIES

Pile fibres	Percentage of original thickness after stated number of footsteps		
	2,000	5,000	10,000
Nylon	82	76	73
Wool	71	62	58
50/50 Wool/Viscose	63	53	50
50/50 Wool/Polypropylene ..	74	72	70

time can be allowed for recovery, and where inter-fibre entanglements which provide obstacles against recovery are low, polypropylene shows up very well, better than wool and very similar to nylon. In a woollen-type woven fabric where there are greater inter-fibre entanglements, polypropylene is not so good; and finally in a tightly constructed worsted fabric polypropylene is at quite a disadvantage compared with wool.

Much remains to be done in evaluating the virtues of polypropylene fibre but these few recovery measurements indicate that it is likely to find uses in pile and loosely constructed fabrics. Here advantage can be taken of another of its virtues: despite its high strength and durability, it is remarkably resistant to pilling. Other strong and durable fibres such as nylon and 'Terylene' are less useful for such purposes largely because of their tendency to pill. When the problems of dyeing are overcome, it is to be expected that polypropylene will find considerable applications in the field of textile fabrics generally, as well as in high-strength industrial products.

TABLE VIII

WOVEN FABRIC CREASE RECOVERY PROPERTIES

Fibre type	Recovery angle, degrees	
	Worsted fabric	Woollen fabric
100 per cent Wool ..	156	152
2/1 Wool/Polypropylene	—	148
1/2 Wool/Polypropylene	—	144
100 per cent Polypropylene	133	141

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Chemistry for Sixth Forms.—Associated Television Ltd have planned a series of programmes on chemistry for sixth forms for schools in the Midlands region during the session 1961–62.

The purpose of the series is to extend the knowledge and experience of the sixth-form student from the limits of the standard syllabus into the world of chemistry beyond. Modern developments will be stressed, and a number of experiments will be shown which would be difficult, if not impossible, for the individual teacher to reproduce in the classroom. The programme adviser for the series is Dr J. H. Pryor.

Further details may be obtained from ATV House, 17 Great Cumberland Place, London, W.1.

Refresher Course for Women Teachers.—The Royal College of Advanced Technology, Salford, is holding a refresher course for women teachers from 28 August to 15 September. It is designed to enable women graduates to return to teaching posts in grammar schools with an up-to-date knowledge of certain aspects of chemistry and physics. Modern developments will be covered by lectures, discussions and practical work on topics such as the nature of chemical bonds; group relationships of the elements; semi-micro techniques in analytical and organic chemistry; modern physics; electronics; and acoustics. Fee 3 guineas. Applications should be sent to the Head of the Department of Chemistry and Applied Chemistry, Salford, 5.

INFRA-RED SPECTROSCOPY FOR UNDERGRADUATES

By N. H. Davies, B.Sc., Ph.D., F.R.I.C.

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During the past few years the author has been concerned with the teaching of molecular spectra in general, and of infra-red spectroscopy in particular, to Grad.R.I.C. and Dip.Tech. students in their final years. Now that a large number of universities and colleges of technology possess infra-red spectrometers it is likely that more and more attention will be paid to infra-red spectroscopy as a special topic in these institutions.

The following notes (based on the Birmingham course) are offered as a guide to those who may wish to introduce practical infra-red spectroscopy into their teaching, so allowing of a thoroughly integrated course of lectures and practical work.

The lecture course consists of about six one-hour lectures. Wherever possible, numerical problems[1] are set in order to drive home the theory. The practical work follows the lecture course, and at about the same time, if possible, a well-known authority on infra-red spectroscopy is invited to give a general talk to the Student Chemical Society.

The lecture course is outlined below.

INTRODUCTORY LECTURE

The first step is to acquaint the student with (i) the different regions of the electromagnetic spectrum,[2] (ii) the units (*e.g.* angstroms, microns, wave-numbers, megacycles per sec) used for each region, (iii) the regions and conditions in which electronic, vibrational and rotational changes are detected.

A short talk (not detailed) on spectroscopic equipment,[3] *e.g.* source, sample cell, monochromator and detector, is then given so that the student realizes that, after all, spectroscopy is an experimental subject, and does not get bogged down in the theory to follow.

The detailed material (less emphasis being laid on those topics printed in italics) for an 'average' final-year class is as follows:

ROTATIONAL SPECTRA[4]

Rotational energy of a diatomic molecule. Selection rules (the student finds a mere statement of the selection rules intellectually unsatisfying; a treatment following Weissberger,[5] without getting involved in too much wave mechanics, is sufficient).

Calculation of bond length from separation of rotational lines.

Triatomic and symmetrical-top molecules.

VIBRATIONAL–ROTATIONAL SPECTRA

Vibrational modes[6] of linear and angular triatomic molecules and *symmetrical-top molecules.*

Vibrational energy of a diatomic molecule (anharmonic oscillator). Rotational fine structure. Overtones.

Parallel and perpendicular bands of triatomic and symmetrical-top molecules.

Intensities of infra-red absorption bands.[7]

INSTRUMENTATION AND TECHNIQUES[8]

Detailed description of a simple double-beam instrument, with explanation of function of each component. Sample handling (gas, liquid and solid).

APPLICATIONS OF INFRA-RED SPECTROSCOPY

Bond lengths, force constants, isotopic shifts, group characteristic frequencies,[9] detection of hydrogen bonding,[10] *etc.* Many examples of the application of infra-red spectroscopy to the elucidation of organic structures are given by Randall *et al.*[11]

In conclusion, to show the subject to be 'live', the lecturer can devote a short time to explaining his special interest or research topic (if in the infra-red field). For instance, the author spends about half an hour on the topic of *solvent effects and infra-red frequency shifts.*

EXPERIMENTAL WORK

An all-important part of the course is the supporting experimental work. Molecular parameters are measured and experience in identification of characteristic organic groups is obtained.

A standard experiment is the investigation of the vibrational–rotational spectrum of hydrogen chloride. Pure dry hydrogen chloride (0·5 g A.R. NaCl + conc. H_2SO_4) is made (by student, only if with previous experience of vacuum techniques!) in a vacuum apparatus and transferred (about 40 cm Hg pressure) to a gas cell. The gas cell is then placed in the infra-red spectrometer (Unicam SP100 with rock-salt prism only) and the spectrum obtained from 2,500–3,000 $cm.^{-1}$ The resolution of rock-salt optics falls off rapidly beyond 3,000 cm^{-1}; if a grating is available more of the R branch can be obtained. Whilst the spectrum is being run, the instrument and techniques (sample cells, nujol mulls, KBr discs etc.) can be explained and queries (theoretical and practical) answered. On such occasions it is particularly noticeable that students are not convinced of the reality of the gap between the P and R branches of hetero-nuclear diatomic molecules until they actually see it!

The separations of the rotational lines are noted, and, from the mean value, the moment of inertia and the

* Dr Davies was formerly Lecturer in Physical Chemistry, College of Advanced Technology, Birmingham.

bond-length of the hydrogen chloride molecule are calculated. Knowing the frequency of the first overtone,[12] the equilibrium vibration frequency and the anharmonicity constant for hydrogen chloride can be calculated, and hence the force constant and heat of dissociation. The different intensities of the rotational bands, which give a measure of the varying distribution of rotational levels, are noted. Those in possession of a grating instrument (or LiF prism) can also observe the isotope splitting due to $H^{35}Cl$ and $H^{37}Cl$.

This experiment is particularly suited to part-time students, as the spectrum is quickly obtained, and yet the information it gives is considerable. The experiment can be varied and/or extended, depending on the time available, by investigating the spectra of hydrogen bromide[13] and hydrogen iodide.[14] The steady decrease in the force constants in going from hydrogen chloride to hydrogen iodide is observed. The important technique of isotopic shift for characterization purposes can be suitably demonstrated by comparing the spectrum of deuterium chloride,[15] made by dropping deuterium oxide (readily available, *e.g.* from Imperial Chemical Industries Ltd) on phosphorus trichloride, with that of hydrogen chloride.

A more complex spectrum can also be investigated, *e.g.* that of methyl chloride, with its parallel and perpendicular bands.[16]

Another standard experiment is the detection of group characteristic frequencies in organic compounds.[9] The scope here is wide and two examples will suffice. The absorption bands due to single and double bonds between carbons, the aromatic nucleus and different substitutions in the benzene nucleus can be observed by studying the spectra of *e.g.* cyclohexane, cyclohexene, benzene, toluene and *o*-, *m*- and *p*-xylene. The carbonyl stretching frequency, and the influence of neighbouring groups on it, can be observed by studying the spectra of *e.g.* acetone, acetaldehyde, acetic acid and acetamide.

A useful exercise is that given by Fieser[17] for the preparation, and identification by infra-red spectra, of the derivatives of 1,2-diphenylethane.* Alternatively, a file of the spectra of about 30 organic compounds (*e.g.* selected from those given by Randall *et al.*[11]) can be prepared and used in conjunction with the chemical properties and empirical formulae to gain experience in the interpretation of spectra.

With some experience behind them, the students can then tackle work of an investigational character. The actual problem will be decided by the research interests of the department. For instance, the department at Birmingham is interested in the changes that occur in coumarin, one of the well-known organic additives used to produce a smooth finish during electroplating. After a time, the efficiency of the coumarin falls off and it has to be replenished. The members of a full-time Grad.R.I.C. class co-operated in investigating the infra-red spectra of coumarin and possible products of change, *e.g. o*-coumaric acid. They were thus able to obtain practical experience (*e.g.* of making nujol mulls) and practice in identifying peaks due to, *e.g.*, 1,2-disubstitution of the benzene nucleus, carbonyl and hydroxyl groups. When each student had interpreted his spectrum a short colloquium was held to compare and collate the information obtained. Work is in hand to obtain crystalline compounds from the bath material. When these are obtained, their infra-red spectra will be compared with the known spectra. In this way it is hoped to ascertain if, *e.g.*, ring-opening of the coumarin occurs in the plating bath.

Again, infra-red investigations are very suitable as projects for final year Dip.Tech. students. Thus, one such project at Birmingham is the preparation and characterization (particularly by infra-red spectroscopy) of crystalline organic complexes of germanium.

In conclusion, it is also desirable (if time permits) that students should have some experience of quantitative infra-red analysis. Suitable experiments are the estimation of *dl*-alanine (KBr disc technique[18]) and the estimation of *o*-, *m*- and *p*-cresol.[19,20]

I am grateful to Dr H. E. Hallam of University College, Swansea, and staff (especially Dr A. Holt) and students at the Birmingham College of Advanced Technology for stimulating discussions.

* The author is indebted to Dr D. G. Lewis for this suggestion.

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Book Reviews

FROZEN FREE RADICALS. G. J. Minkoff. Pp. ix + 148. *London: Interscience Publishers Ltd; New York: Interscience Publishers Inc.*, 1960. 36*s*.

This book is one of the results of the tremendous burst of activity in research on the formation and immobilization of free radicals that has been witnessed during the last five or six years, and which centred upon the National Bureau of Standards in Washington, which in 1956 launched a three-year programme in this field. Dr Minkoff was himself a member of the Washington team for a year, and with his well-known background of work on free-radical reactions is clearly highly qualified to present, as he does here, an account of the current status of experiment and thought on this topic. However, this book goes further than is implied in what has been said above; the preliminary chapters describe the historical work of Dewar, Strutt and others who were carrying out the pioneer experiments in this field some 60 years ago, and also review the general experimental methods for the production and detection of free radicals.

There is also a discussion of the rather elaborate experimental methods developed to cope with problems associated with trapping experiments at liquid helium temperature and the detection and estimation of concentrations of frozen free radicals by E.S.R. and optical spectroscopy. Further chapters deal with the statistical treatment developed to provide the theoretical background to the study of radical trapping, and give accounts of results obtained with atoms and diatomic, triatomic and polyatomic radicals. In the latter case, polymer and biological systems are discussed only very briefly, since they do not fall within the main scope of the book which, as the title indicates, is designed to include only low-temperature trapping.

This most readable book presents the methods and results of one of the most topical fields of physicochemical research at a time when a large body of work has just been completed. It gives an admirable account of these developments, and will serve both as an absorbing survey of radical trapping to those not personally experienced in the field and as a stimulating source-book for those pursuing further studies of frozen free radicals.

A. D. JENKINS

MASS SPECTROMETRY AND ITS APPLICATIONS TO ORGANIC CHEMISTRY. J. H. Beynon. Pp. xii + 640. *Amsterdam: Elsevier Publishing Co.; London: D. Van Nostrand Co. Ltd*, 1960. 120*s*.

The author has gained great experience in the field covered by this book, and in particular he has studied the qualitative identification of organic compounds by mass spectrometry. He writes that if it is possible to obtain the mass spectrum of a substance of completely unknown nature, more information can generally be obtained from this spectrum than by any other single technique. The book gives a full account of the experimental methods of mass spectrometry and many illustrations of the way in which deductions can be made from a mass spectrum. Over 2,000 references to original papers are given. The book seems likely to be an important work of reference for some time.

Beynon has pioneered the use of high-resolution mass spectrometry in organic chemistry. This method uses the deviations of atomic masses from whole numbers as a means of identification. Combinations of atoms can be identified in the same way, and thus it is possible to establish the chemical formula of those fragments of a molecule which appear as ions in a mass spectrum. To help in this identification an appendix tabulates exact masses of various combinations of carbon, hydrogen, nitrogen and oxygen. This appendix also gives isotope abundance ratios for these atomic combinations.

The correlation of molecular structure and mass spectra, with sections dealing with different types of compound, is discussed in a chapter of nearly 100 pages. Sometimes mechanisms for the formation of the more prominent ions in a mass spectrum can be proposed out of ideas derived from ordinary chemical experience, although mechanisms proposed by different authors may be at variance. Many of the breakdowns and rearrangements undergone by ions formed by electron impact seem to be of a complex kind, however, and the correlation of mass spectra and molecular structure is proceeding mostly along empirical lines.

Instruments and associated problems, exact mass measurement and the types of ions in mass spectra are dealt with in other chapters, one of which contains an account of the many other applications of mass spectrometry in chemistry, including quantitative analysis.

Mass spectrometers with the necessary high resolution for the kind of investigation described in this book are now becoming commercially available. It seems that a mass-spectrometry laboratory fully equipped for all kinds of chemical work will in the future have to contain several different instruments (probably all expensive), and considerable problems of documentation and filing of spectra will eventually arise if many laboratories undertake work in this field.

A. J. B. ROBERTSON

ORGANIC REACTIONS. VOLUME XI. A. C. Cope, Editor-in-Chief. Pp. vii + 501. *New York: John Wiley & Sons Inc; London: John Wiley & Sons Ltd*, 1960. 96*s*.

Generally speaking, a chapter in this excellent series of volumes was devoted to the description of a well-known reaction, very often carrying the name of one particular chemist. This afforded a convenient device for dealing with subjects having a large number of

practical applications. In the present volume, the five chapters are of a somewhat different type. Thus the first, entitled 'The Beckmann Rearrangement', does not call to mind any particular condensation or other experimental operation, but rather a widely-experienced change which as a rule is not, in itself, a part of synthetic procedure. In fact, the chapter gives a very up-to-date and pleasant account of the theory of Beckmann rearrangements of oximes and analogous compounds. It ends with the usual tabular survey, and no fewer than 593 references are given.

Chapter 2, on the Demjanow: Tiffeneau–Demjanow ring expansion, contains a thorough-going account of the various manifestations of these changes, including some in heterocyclic chemistry. The application of the processes to synthesis is discussed, and 110 references are given.

Chapter 3 is a review of the arylation of unsaturated (but not aromatic) compounds by means of diazonium salts; Meerwein discovered that this could be accomplished in presence of copper salts. Among the unsaturated compounds mentioned are α,β-enoic acids and their nitriles, 1,3-dienes and benzoquinones. It will be remembered that the somewhat related Gomberg–Bachmann reaction was discussed previously (Volume II, 1944). The present chapter deals with both theoretical and experimental matters.

It is concluded that the Favorski rearrangement of haloketones, considered in chapter 4 (127 references), most commonly goes by way of a cyclopropanone intermediate, an internal S_N2 displacement on the halogen-bearing carbon atom leading to inversion of configuration.

The last chapter in the book occupies 168 pages, 391 references being cited. The title, 'Olefins from Amines: The Hofmann Elimination Reaction and Amine Oxide Pyrolysis,' suggests that both theoretical and experimental material would be included, and this is indeed provided in a pleasant and convincing manner. The Ingold–Hughes work on mechanism, direction of elimination and so on is admirably set out. Numerous examples of actual experimental procedures are given in addition to the customary tabular survey. The chapter may be thought of as organic chemistry at its best and is a fitting end-piece to this first-rate collection of memoirs.

E. E. TURNER

ADVANCED ORGANIC CHEMISTRY. Third Edition. G. W. Wheland. Pp. xi + 871. *New York: John Wiley & Sons Inc; London: John Wiley & Sons Ltd*, 1960. 140*s*.

For the past 15 years Wheland's *Advanced Organic Chemistry* has been one of the world's best-known treatises on theories of organic chemistry, and so its reappearance in a new, revised edition will be welcomed everywhere. The third edition has about 50 additional pages of text; the order of a few of the chapters has been altered, but beyond this the text has been revised throughout, not merely by reference to newer work, but also by the curtailment of discussion on topics of waning interest, and by the rephrasing of many sections so as to accord with present concepts and terminology.

The book nevertheless retains its distinctive character in that it gives Professor Wheland's personal selection of the significant themes of organic chemistry and deals with these in great detail. It shows how the historical development of theories has depended upon the discovery of new experimental facts, how newer techniques have been applied, and above all the extent to which our present concepts of organic chemistry have been substantiated by experimental evidence and in what respects certain of them remain today as plausible but unproven speculations. Throughout it is critically controversial and so, for senior students, can be warmly commended as a corrective to the formal 'comprehensive textbooks' which so often present theories as 'laws of science' which should be learned and not questioned.

About 60 per cent of the book deals with molecular structure, beginning with a non-mathematical description of the nature of valency bonds, explaining the concept of resonance and developing into a detailed discussion of the stereochemistry of carbon compounds. Conformational analysis is now mentioned as the logical outcome of Baeyer's strain theory, but its implications in connection with the optical properties of molecules, or of molecular reactivity, are scarcely touched upon. The remainder of the book deals adequately only with molecular rearrangements of different types and with the historical section of free-radical chemistry that had to do with triphenylmethyl and its analogues. In this part of the book, too, the emphasis is upon structural aspects of organic reactions and not on the many important implications of kinetic and thermodynamic studies. It is surprising for instance, especially in an American book, to find that discussion of Hammett's $\rho\sigma$ relationship can be confined to three pages and that the significance of his h_0 function is mentioned only in the preface. English readers will notice how little the S_N1 and S_N2 symbolism is used except as an abbreviation and that discussion of substitution processes is not deemed worth even a short chapter. Again the kinetics of tautomeric change do not receive treatment, whilst uses of isotopes are included only in discussion of structural problems.

Still, in writing an advanced treatise it is far better for an author to be selective and thorough than to be superficial but extensive. Professor Wheland's style of English is such that when the text is read slowly both the clarity of his arguments and his masterly presentation of chemical theories can be appreciated with pleasure. Again, the clarity of the structural formulae and the excellence of the typography both deserve special commendation.

W. A. WATERS

AEROSOLS: SCIENCE AND TECHNOLOGY. Edited by H. R. Shepherd. Pp. xiv + 548. *New York: Interscience Publishers Inc; London: Interscience Publishers Ltd*, 1961. 169*s*.

The aerosol industry in its established form is now well into its second decade and a wide technical literature has grown up covering the various aspects of this packaging technique. Prior to the publication of this American book only one general work of reference, of British origin, existed and a further work is therefore welcome.

The aerosol industry is more advanced in the United States than anywhere else in the world and authoritative first-hand information from American experts is of the greatest value to workers all over the world. This book has been compiled by 19 contributors drawn from various branches of the American aerosol industry, under the editorship of a well-known personality in this field.

At first sight the book appears to be comprehensive, but on closer reading it becomes apparent that it has shortcomings. Much of the information is out of date to an extent which cannot be entirely blamed on delays of publication. Statistical information, for example, closes with 1957 figures; later information has been freely available from published sources for a considerable time. A second major shortcoming is duplication in chapters by different contributors, and would suggest rather careless editing. Individual authors appear sometimes to sponsor the views and even the products of their own companies, and some misleading information has been included, apparently without editorial comment. A typical example is the implied suitability of uncoated glass aerosol bottles, where experimental evidence as well as plain common sense would suggest that the practice is highly undesirable.

There are also omissions in the text; for example, the book provides no information on commercial aerosol packing methods. This cannot be regarded as a matter of trade secrecy and the reader would expect such information, together with a review of the types of equipment available.

These criticisms, however, do not detract from the overall usefulness of the work. The authors have wide experience, and were the book available at a lower price, despite its shortcomings it would warrant a wide readership not only within the aerosol industry itself but also amongst those concerned with products suitable for packing in this way. Unfortunately, even by American standards the book is extremely expensive, and this is bound to restrict its use to those within the industry, particularly as the difference between the amounts of information in this and the British book is insufficient to justify a difference in cost of almost £5. If a second edition is prepared, the publishers will have to aim at a lower price and more up-to-date information if the book is to appeal to readers outside the U.S.A.

I. GREENFIELD

SEMI-MICRO QUALITATIVE ANALYSIS. (A supplement to Part V of PRACTICAL CHEMISTRY.) T. A. Muir. Pp. iv + 44. *London: Heinemann Ltd*, 1961. 3*s*.

This small book, a supplement to Part V of *Practical Chemistry* by J. Lambert and T. A. Muir, meets the needs of students preparing for the G.C.E. 'A' level examination in inorganic qualitative analysis.

The apparatus described and the technique employed are rapidly becoming standard in schools working on this scale; the book is clearly expressed and sound in principle, particularly with regard to the quantity of material to be used for the systematic scheme for cations.

Two schemes of analysis following the traditional pattern are given—procedure A, modified to the restricted needs of the 'A' level syllabus with no more than one radical in a group, and procedure B, where no such restrictions are imposed. These schemes are well and clearly presented but one wonders why ammonium sulphide is still used for dividing group II sulphides when there are other less objectionable reagents available.

In an otherwise very commendable work there is one discordant note—in procedure A on p. 21, lead is tested for with potassium chromate in a solution containing a mixture of hydrochloric and nitric acids.

The book is well produced, attractively priced and, as far as was noticed, free from printers' errors.

H. HOLNESS

PUBLICATIONS RECEIVED

RADIOACTIVITY IN THE SERVICE OF MAN. J. F. Duncan. Thomas Cawthron Memorial Lecture, No. 34, 1959. Pp. 43. *Nelson, New Zealand: R. W. Stiles & Co. Ltd*, 1960.

THE ORGANIZATION AND FINANCING OF RESEARCH IN BIOCHEMISTRY AND ALLIED SCIENCES IN GREAT BRITAIN. (Proceedings of a meeting held jointly by the Biochemical Society and Section I [Physiology/Biochemistry] of the British Association for the Advancement of Science, September, 1960.) Edited by K. S. Dodgson. Pp. 51. *London: The Biochemical Society*, 1960. 2*s*. 6*d*. (Obtainable from Dr P. N. Campbell, Courtauld Institute, Middlesex Hospital, London, W.1.)

BRITISH STANDARD.

1991 : Part 1 : 1954. Amendment No. 3. Letter Symbols, Signs and Abbreviations.

(A full revision of Part 1 will be made in a new edition which it has been decided to prepare. In the meantime, in order to avoid inconsistencies between Part 1 and the new Parts which are at an advanced stage of preparation, the revisions given in this list are recommended for use forthwith.)

Institute Affairs

LICENTIATE GRADE OF MEMBERSHIP

A major step towards the introduction of a Licentiate grade of membership of the Institute was taken at a Special General Meeting held on Thursday, 20 July.

At that meeting a resolution approving changes in the By-laws to provide for the admission of Licentiates and to define their status, rights and obligations was carried by an overwhelming majority of members voting personally and by proxy. The proposed new By-laws will not become effective until they are allowed by the Privy Council and they have been duly submitted for such final approval.

A resolution embodying a recommendation by the Council that the annual subscription of a Licentiate shall be three guineas was also approved. A further resolution authorizing the Council to take such steps as may be necessary to enable the Benevolent Fund to be used for the benefit of Licentiates and their dependants, and the dependants of deceased Graduate Members, was also carried on the understanding that further consideration would be given to the possibility of including Graduate Members as well as their dependants among those eligible for assistance.

A fuller report of the meeting will be published in the September issue of the *Journal*.

In the expectation that the new By-laws will be allowed by the Privy Council without modification, the Council has already given some consideration to the drafting of Regulations for admission to the new grade and to making such amendments as may be necessary in the conditions of admission to other grades of membership. It is intended that these Regulations shall follow the lines of the proposals outlined in the Memorandum of December, 1960, and reiterated in the Statement appended to the Notice of the Special General Meeting.

Subject to agreement being reached on outstanding questions the Council should be in a position to promulgate Regulations for Admission to Licentiateship in October. It is unlikely that these will be published before November or December or that applications can be considered before the end of the year.

DIPLOMA EXAMINATIONS

Examinations for Postgraduate Diplomas in Applied Chemistry will be held in the autumn in London or elsewhere at the discretion of the Council. The examination in Branch E will be held in the week beginning **Monday, 9 October, 1961.** The dates of the examinations in other branches have not yet been confirmed, but will be at about the same time. Candidates for these examinations should have returned application forms to the Institute not later than **Friday, 11 August.** The last date for the receipt of Entry Forms is **Friday, 1 September.**

CONFERENCE OF LIAISON OFFICERS IN TECHNICAL COLLEGES

The fourth national conference of Liaison Officers was held in Queen Elizabeth College, London, on 1 July, the Chair being taken by the President. The meeting was attended by 84 Liaison Officers and a number of representatives of the Institute, including Professor H. Burton, *Hon. Treasurer*, Mr G. Dring, Professor R. A. Morton, Dr F. A. Robinson and Mr E. J. Vaughan, *Vice-Presidents*; Professors C. C. Addison and W. J. Hickinbottom, and Drs A. G. Sharpe, D. A. Frye and A. D. Mitchell, *Examiners*; and Drs K. E. Howlett, P. F. G. Praill and L. Saunders, *National Certificate Assessors*. Mr W. J. Richards, C.B., C.B.E., Director, Staff College for Further Education, Mr J. Maitland-Edwards, Staff Inspector, Ministry of Education and Mr W. S. Gray, H.M. Inspector, Scottish Education Department, attended by special invitation.

Mr W. J. Richards opened the Conference by giving a brief account of the aims and functions of the proposed Staff College for Further Education and outlining the present development of the plans. He indicated the range of courses that would probably be available, but emphasized that the prime purpose of the Staff College would be to provide a national centre at which senior staff from further education establishments could meet and discuss problems of mutual concern with senior personnel from industry, the Scientific Civil Service, Local Education Authorities, Ministry of Education, universities and schools. Several comments and suggestions on the development of the Staff College were put forward by Liaison Officers in the general discussion.

The remainder of the morning session was devoted to a discussion of the proposed Licentiateship grade of Institute membership. This was introduced by Mr E. J. Vaughan, C.B.E., Chairman of the Study Group on Qualifications, who summarized the present position with respect to the proposed new grade of membership and outlined the academic qualifications and requirements that might afford admission to Licentiateship.

After luncheon, which was provided by the Institute in the College, there were discussions on the Graduate Membership examination, examiners' reports and ancillary subjects. An opportunity was also taken of informing the Liaison Officers of an amendment to Regulation F3 whereby students in an unrecognized college would under certain circumstances be able in future to apply for exemption from the Part I examination on the basis of their performance in the H.N.C. examination.

Liaison Officer.—Dr J. J. Betts, *Fellow*, head of the department of chemistry and biology at the Harris College, Preston, has been appointed Liaison Officer at the College in succession to Dr S. Skidmore, who is now Vice-Principal.

A complete list of Institute Liaison Officers was published in the June issue of the *Journal* (p. 232).

Institute Representatives.—The Council has nominated the following *Fellows* to represent the Institute :—

Regional Advisory Council for Higher Technological Education, London and Home Counties: Advisory Committee for Applied Chemistry and Chemical Engineering: Dr S. A. Miller in succession to Dr N. Booth.

Regional Advisory Council for Further Education in the South West: Science Advisory Committee: Mr R. A. Rose in succession to Mr E. G. Whittle.

Acton Technical College: Governing Body: Miss J. L. Scott.

Enfield Technical College: Governing Body: Dr C. Simons.

Harrow Technical College: Governing Body: Mr P. A. Raine.

Hendon Technical College: Governing Body: Dr S. A. Miller.

Isleworth Polytechnic: Governing Body: Mr R. J. Cole.

Oxford College of Technology: Science Advisory Committee: Dr F. M. Brewer, M.B.E., in succession to Professor H. M. Irving.

Sunderland Technical College: Chemistry, Metallurgy and Physics Advisory Committee: Dr J. Gibson.

A complete list of Institute representatives appeared on pp. 230–1 of the *Journal*.

Lecture Series 1961.—The Council has authorized the shortening of the title of the series *Lectures, Monographs and Reports* to *Lecture Series*. This, it is thought, more accurately reflects the type of material published though it is proposed to continue to include review-type material and surveys of matters of wide interest. At the same time a new two-colour cover will be introduced.

The new series is being inaugurated with three special contributions, which will be distributed shortly :

No. 1. *Atmospheric Photochemistry*, by Sir Harrie Massey, of University College, London, and Dr A. E. Potter, head of the Reaction Kinetics Section, National Aeronautics and Space Administration, Cleveland, Ohio. 5*s*.

No. 2. *A Chemist's Introduction to Statistics, Theory of Error and Design of Experiment*, by Dr D. A. Pantony, of the Imperial College of Science and Technology, London. 5*s*.

No. 3. *Recent Developments in Polarography*, by Dr G. W. C. Milner, A.E.R.E., Harwell. 5*s*.

Exhibition of Laboratory Apparatus.—An exhibition of chemical laboratory apparatus will be held in the Royal College of Science and Technology, Glasgow, C.1, on Wednesday, 20 September (10 a.m.–7 p.m.), Thursday, 21 September (10 a.m.–7 p.m.) and Friday, 22 September (10 a.m.–12.30 p.m.). The exhibition will be arranged in two chemistry laboratories, Rooms 302 and 304, on the third floor of the main building of the College.

This is the second such exhibition organized by the Glasgow and West of Scotland Section, and up-to-date instruments and apparatus will be on view. The exhibition stands will be staffed by personnel competent to answer queries and describe the operation of the equipment. Admission is free.

PERSONAL NOTES

News of Hon. Fellow

Sir Harold Hartley, G.C.V.O., C.B.E., M.C., F.R.S., has been made an honorary member of the Institute of Fuel.

Honours and Awards

Dr A. K. Holliday, *Fellow*, senior lecturer in the department of inorganic and physical chemistry, University of Liverpool, has been awarded the degree of D.Sc. by the University of Leeds for his work on the chemistry of boron compounds and studies of reactions in liquid ammonia.

Dr J. W. Ladbury, *Associate*, has been awarded the 1960–61 Silver Medal of the Plastics Institute. He was recently seconded from Imperial Chemical Industries Ltd, Plastics Division, to British Visqueen Ltd, Stevenage.

Dr Muriel L. Tomlinson, *Fellow*, University demonstrator in organic chemistry at Oxford, has been granted an award under the Royal Society and Nuffield Foundation Commonwealth Bursaries Scheme to enable her to study polydentate compounds at the University of Sydney for about three months early in 1962.

Societies and Institutions

Dr R. R. Garran, *Fellow*, staff manager, Alkali Group, I.C.I.A.N.Z. Ltd, Melbourne, has been elected President of the Royal Society of Victoria.

Mr H. V. Potter, *Fellow*, has been elected into the Court of Assistants, The Worshipful Company of Horners.

Educational

Mr K. W. Allen, *Fellow*, lecturer in physical and inorganic chemistry, Northampton College of Advanced Technology, is to be visiting research associate and instructor at the crystallography laboratory, University of Pennsylvania, U.S.A., for 12 months from 1 September, on a Fulbright Scholarship. He will work on the structure of gas hydrates.

Dr J. F. Duncan, *Associate*, reader in radiochemistry, University of Melbourne, left Australia early in June on sabbatical leave. He expects to spend about four months at the Chalk River Research Laboratories, Atomic Energy of Canada Ltd, followed by visits to universities in the U.S.A. and U.K.

Mr P. R. Falkner, *Associate*, lecturer in chemistry, Nottingham and District Technical College, has been appointed senior lecturer in analytical chemistry.

Dr M. Gordon, *Fellow*, senior lecturer in physical chemistry, Imperial College of Science and Technology, has been appointed to the University of London readership in physical chemistry tenable at that college.

Dr R. A. W. Green, *Fellow*, has been appointed Associate Professor of Inorganic Chemistry, University of Sydney. He was formerly senior lecturer.

Dr W. Hamilton, *Associate*, has relinquished his post of development chemist, Brown & Polson Ltd, to take up an appointment in the chemistry department of the University of Malaya in Singapore.

Mr I. S. Hunt, *Fellow*, has resigned his post as chief research chemist, Hickson's Timber Impregnation Co. (N.Z.) Ltd, to take up a post on the staff of the University of the Andes, Venezuela, where he will be in charge of the timber preservation division of the forest products research laboratory.

Dr D. I. Jenkins, *Associate*, has been appointed chief chemist of the sanitary engineering research laboratory in the University of California. He was formerly research biochemist.

Dr I. T. Millar, *Fellow*, has been appointed senior lecturer in chemistry, University College of North Staffordshire, as from 1 October. He was formerly lecturer in organic chemistry.

Dr V. V. Modi, *Associate*, senior lecturer in biochemistry, University of Baroda, India, is spending about a year at the animal science laboratory, University of Illinois, under that University's exchange programme. He has been there since May.

Dr V. S. K. Nair, *Associate*, senior lecturer in chemistry, College of Advanced Technology, Birmingham, visited laboratories in Scandinavia, Germany, Switzerland and Italy on an O.E.E.C. Senior Visiting Fellowship of two months. He has since been visiting India and lecturing to various national research institutes. He returns to this country in September.

Dr Eva M. Philbin, *Fellow*, senior lecturer in organic chemistry, University College, Dublin, has been appointed to the Chair of Organic Chemistry tenable at that college. Dr Philbin is the first woman to occupy a chair of organic chemistry in Great Britain and Ireland.

Mr C. A. Russell, *Associate*, has been appointed senior lecturer in organic chemistry, Harris College, Preston.

Professor F. Sebba, *Fellow*, Professor of Physical Chemistry at the University of Witwatersrand, is to spend a year's study leave working in the department of mining at the Royal School of Mines, London, being assisted by a grant from the Ernest Oppenheimer Memorial Fund; he will be the guest of the School. He will work on a technique he has evolved for the concentration of precious and semi-precious metals from solution by ion flotation.

Dr P. P. G. L. Siriwardene, *Fellow*, is returning to Ceylon this month having spent some time at the Harwell Isotope School on a fellowship of the International Atomic Energy Agency, Vienna. He will take over the running of a new radioisotope laboratory in the University of Ceylon, Colombo, which is nearing completion under the supervision of an I.A.E.A. expert, in addition to his duties in the department of chemistry at the University.

Dr K. S. Srinivas, *Associate*, chief chemist, Sirsik Ltd, Sirpur, India, has taken up a research post at the department of organic chemistry, University of Montreal, Canada.

Mr B. E. Towlson, *Associate*, formerly head of the science department, College of Technology, Kumasi, Ghana, has been appointed head of the department of science at the College of Arts, Science and Technology, Kingston, Jamaica.

Dr J. H. Wilkinson, *Fellow*, has recently been elected to a research fellowship at Mander College, Bedford.

Public and Industrial

Mr C. C. Albertyn, *Associate*, has been appointed works chemist, African Metals Corporation Ltd. He was previously agricultural research assistant.

Mr H. G. Badman, *Associate*, has left the department of agricultural chemistry, Queen's University, Belfast, to take up a post with Twyford Laboratories Ltd.

Dr F. H. Banfield, *Fellow*, director of research, British Food Manufacturing Industries Research Association, has been appointed technical director of C. Shippam Ltd.

Dr W. Bridge, *Associate*, deputy works manager at the Cassel Works of the General Chemicals Division, Imperial Chemical Industries Ltd, has been appointed Works Manager of the Wade Works, Northwich, with effect from 1 January, 1962.

Mr W. Burns, *Associate*, has relinquished his post of research chemist, Reckitt & Sons Ltd, Hull, to take up an appointment with the North British Rubber Co. Ltd, Dumfries.

Mr L. J. Coleman, *Associate*, has taken up the position of control laboratory manager, Leicester, Lovell & Co. Ltd, having resigned from the post of development chemist, C. & J. Clark Ltd, Street.

Dr C. B. Davies, *Fellow*, head of the oil products development division, Shell International Petroleum Co. Ltd, has taken up an appointment as manager of the Thornton Research Centre, Shell Research Ltd, Chester.

Mr G. I. Early, *Associate*, has taken up a position as senior chemist in the research and development department of the Midlands Division of the Central Electricity Generating Board.

Mr A. E. Frankland, *Fellow*, has been transferred to the central research division of the Weyerhaeuser Co., Longview, Washington, as development scientist responsible for liaison between central research and

Canadian operations. He was formerly technical director of the hardwood, lumber and veneer division, Mattawa, Ontario.

Dr R. Genders, M.B.E., *Fellow*, has been elected to the board of Arnott & Harrison Ltd.

Dr G. C. Gibbons, *Fellow*, formerly chief chemist, Domestos Ltd, has been appointed technical director of the company.

Dr M. S. Habib, *Associate*, has been appointed chief analyst, Burroughs Wellcome & Co. (Pakistan) Ltd, Karachi, as from 21 August.

Mr E. E. Haddon, *Fellow*, formerly director of chemical defence research and development at the War Office, has been appointed director of the Chemical Defence Experimental Establishment, Porton, in succession to Dr E. A. Perren (*q.v.*) as from 24 July. Mr Haddon has been promoted to Chief Scientific Officer as from that date.

Mr K. G. Hargreaves, *Fellow*, chief chemist, James Anderson & Co. (Colours) Ltd, has been appointed a director of the company, a member of the Geigy Group, with effect from 1 July.

Dr R. Heap, *Fellow*, has been appointed consultant to the Watford Chemical Co. Ltd.

Mr Allan Hill, *Associate*, technical manager of the plastics chemical division, the Geigy Co. Ltd, has been appointed a director of the company with effect from 1 July.

Mr J. S. Hughes, *Fellow*, manager of the process and product development department, Midland Silicones Ltd, has been appointed development director of the company.

Dr W. Jeffers, *Associate*, formerly research chemist, Borax Consolidated Ltd, has taken up an appointment as a research chemist with E. I. du Pont de Nemours Ltd, New Jersey, U.S.A.

Mr H. W. Jones, *Fellow*, formerly group manufacturing manager of Aspro-Nicholas Co. Ltd, has joined Process Plant Contractors (Campbell) Ltd as technical manager.

Mr G. M. Lambert, *Associate*, has left Allied Colloids Manufacturing Co. Ltd to take up the position of assistant editor of the new journal *R. & D.* (*Research and Development for Industry*).

Dr K. O. Lee, *Associate*, chief chemist and rubber technologist of the Lee-Healey Co. Ltd, has been appointed to the board of directors of the company.

Dr R. Lessing, *Fellow*, has relinquished his position as managing director of Hydronyl Ltd, which he has held since the formation of the company in 1914, and has been appointed deputy chairman.

Mr D. A. B. Llewelyn, *Fellow*, has resigned his post as deputy scientific officer and director of the oil synthesis branch, Ministry of Power, and has joined the research and technical development department, British Petroleum Co. Ltd.

Mr W. Manz, *Associate*, has resigned his post as senior lecturer in paint technology, College of Advanced Technology, Birmingham, to join E. I. du Pont de Nemours & Co., London.

Dr G. E. Mapstone, *Fellow*, formerly chief chemist and factory manager, Dermacult S.A. Pty Ltd, Johannesburg, has joined the development department of African Explosives and Chemical Industries Ltd.

Mr P. J. March, *Fellow*, has been appointed a director of the Shell Chemical Co. Ltd, with effect from 30 June.

Mr J. C. G. Nisbet, *Fellow*, has been appointed technical director, Lever Pacocha S.A., Lima, Peru, as from 1 September. He was formerly assistant general works manager, Van den Berghs & Jurgens Ltd, Purfleet.

Mr R. J. Powell, *Fellow*, of the Shell International Petroleum Co. Ltd, has been appointed refinery superintendent, Balikpapan Refinery.

Dr F. A. Robinson, *Vice-President*, research director of Allen & Hanburys Ltd, has been appointed executive chairman of The Crookes Laboratories Ltd. He will take up his duties on 1 September. Dr Robinson is hon. treasurer and a former chairman of the Biochemical Society, and author of books on chromatography, antibiotics and the vitamin B complex.

Mr W. L. Sheppard, *Fellow*, formerly research analyst, animal nutrition division, Unilever Ltd, has taken up an appointment as head of the physical assay division, standards department, Boots Pure Drug Co. Ltd.

Mr C. L. Walker, *Associate*, works manager, F. T Wimble & Co. Ltd, Wellington, New Zealand, has been transferred to the Melbourne, Australia, factory of the company as general manager, research and development division.

Dr A. W. White, *Associate*, formerly a technical assistant, patents division, Shell Research Ltd, is now assistant to the patents manager, Albright & Wilson Ltd.

Mr E. H. Williams, *Associate*, formerly chemical engineer, Murgatroyd's Salt & Chemical Co. Ltd, has joined the process development department of Midland Silicones Ltd.

Retirements

Mr G. N. Charrett, *Associate*, has retired from his position of chemist, North Thames Gas Board.

Dr E. A. Perren, *Fellow*, director of the Chemical Defence Experimental Establishment, Porton, has retired, but will continue to serve in the Establishment's research laboratory.

Mr A. T. Wilford, *Fellow*, retired on 29 July as director of research, London Transport. He has held this position since May, 1950.

Dr F. C. Wood, *Fellow*, research chemist (managerial), Tootal Broadhurst Lee Co. Ltd, retired on 30 June, and has been appointed part-time consultant to the firm. He has spent over 42 years with the organization

Section Activities

Cumberland and District

Summer Excursion. As on several previous occasions, the outing on 10 June took the form of an expedition to a part of the Lake District where there are features of geological as well as scenic interest. The excursion was once more arranged by Dr F. H. Day, assisted by Mr N. Thomson. A party of members and their friends assembled at Castle Inn, Bassenthwaite, and then proceeded to the little-visited north-western corner of the Lake District. Cars were parked at Fellside and the party walked up the valley of Dale Beck, where a picnic lunch was enjoyed. The more energetic members (about half of the party) then followed Dr Day up the valley, up Swinburne Gill, past the old workings of Red Gill mine and up on to the higher ground of the Caldbeck Fells. Here, at 2,000 ft, they saw the overthrust Skiddaw Slates above the geologically higher volcanic rocks of the Borrowdale series. They then descended to Thief Gills, to the head of Roughton Gill, across Iron Crags and down to the extensive old mine workings where the rest of the party, led by Mr Thomson, were rejoined.

Roughton Gill, where mining took place about a century ago, has long been noted, not for the quantity but for the variety of its minerals. These are characteristically products of the oxidation zone of the veins, including not only the primary sulphides of lead, copper and zinc, but also oxides, carbonates, sulphates, silicates and phosphates of these metals in variety and some complexity. More than 36 mineral species have been recorded from this locality, and members were able to see or collect as many as 22 of them—which reflects not only their assiduity but also the low efficiency of separation of the ores by former methods. The return journey included tea at the Armathwaite Hall Hotel. The weather held fine until tea time, and so all were able to enjoy this excursion, which continues to be a popular annual event.

Glasgow and West of Scotland

Works Visits. Three works visits were arranged for June. On 8 June, members were shown over the whisky-blending and bottling plant of John Walker & Sons Ltd, Kilmarnock. The conducted tour ended at the modern bottling hall. Dr W. D. Williams thanked the company for the courtesy shown to the visitors.

On 15 June the venue was the Southbar Cattle Breeding Centre of the Scottish Milk Marketing Board. This visit proved to be of considerable interest, and a lively discussion of biological and chemical problems took place at an informal tea after the conducted tour of the Centre. Dr A. P. Kenny proposed the vote of thanks to Mr A. R. Campbell, veterinary director, and his staff.

The summer programme ended on 19 June with a visit to Fibreglass Ltd, Glasgow. The members, in small groups, witnessed the manufacture, spinning and control of the fibreglass, the difficulties at each stage being discussed and explained in a lucid manner by the staff. Mr W. G. D. Wright expressed the appreciation of the members for a pleasant and instructive afternoon.

London: Summer Visits

Visit to Rothamsted. A party paid a visit to Rothamsted Experimental Station at Harpenden on 31 May. Members and their guests were welcomed by Dr G. W. Cooke, head of the chemistry department, on behalf of the director. He gave a brief appreciation of the work of the Station as a whole, and outlined the particular aspects which are the concern of the chemistry department. Dr K. A. Lord then gave an account of the interesting work carried out by the department dealing with insecticides, and after that the party split into various groups to tour the Station grounds.

One of the interesting units visited was that which was preparing, on a pilot-plant scale, protein extract from green fodder. The Broadwalk wheat experiment was also visited, and the effects of 119 years of continued manuring of different kinds was explained. A similar long continuous experiment on grassland was also seen.

Tea was provided by the hosts, and the vote of thanks was passed to the director and staff of the Station by Dr C. Simons. After tea a large number of visitors stayed behind to visit further experimental plots, to be shown over the various laboratories and to discuss the work carried out therein.

De Havilland Aircraft Company. A party visited the Hatfield factory on 8 June. Mr H. D. Wright welcomed the party, which then split into several small groups to be escorted round the works by senior apprentices.

In a fairly comprehensive tour lasting nearly two hours, members saw the work in progress in the machine shops, the metal-fabrication shops, and the assembly line of the world-famous De Havilland Comet aeroplane, which could be seen in progressive stages of assembly. Members of the party were conducted through one of these aircraft which had reached an advanced stage of construction. On view also were the latest 'Trident' aeroplanes, fitted with engines at the rear.

Finally, a visit to the painting and finishing hangars was made, where among several aircraft on view were examples of famous aircraft which dated back to the 1920s and 1930s and are still in use.

Light refreshments were provided and Mr J. Ratcliffe thanked the company on behalf of the Section for an enjoyable and instructive afternoon.

Stewarts and Lloyds Ltd. On 12 June, a party of members visited the Corby Works of Stewarts and

Lloyds Ltd. This company, with several locations in the Corby area, is one of the largest steel tube-makers in the world.

After the party had proceeded to a quarry by coach, the operation of a dragline excavator was explained. The excavator seen, with a boom over 300 ft long constructed on site from the company's own tubing, has been in commission for a year, and has a bucket with a 22-cu. yd capacity. The workable iron ore at this site is some 9 ft thick and 100 ft below the surface, and supplies in the vicinity are computed to last for about 30 years.

The iron content of the ore in this area is comparatively low, being about 28 per cent, and production is geared to handle ore of this composition. After extraction of the ore the land is subsequently restored to agricultural use or planted with trees.

During the journey back to the works it was possible to see the extent of the company's activities in the area. The party arrived in time to see hot metal proceeding from a blast furnace. Slag from this plant, which has a capacity of 2,400 tons per day, is used as road metal.

After an excellent lunch generously provided by the company, members saw the impressive sight of steel-making by the basic Bessemer process. Molten iron is received by rail in ladles from the blast furnace. A combination of art and science was evident here. From general appearance and that of the smoke the foreman is able to gauge when the impurities have been reduced to a sufficiently low level, and receives the results of a rapid determination of phosphorus content from the laboratory by electric signal lights. The process is completed in about 12 minutes.

High-grade steel is produced in two small electric furnaces operating mostly on scrap. Some surprise was expressed by members at the low voltage used, which is of the same order as the domestic supply.

The rolling process was then followed. The steel ingots emerging from the soaking pits pass through two reversing mills and then a continuous mill, and emerge as strips in coils up to 16 in wide. This is used for making tubes.

About half a million tons of tubing of up to 4 in diameter are made in the continuous weld mills, where the reheated strip is bent into tubular shape and the edges butt-welded by pressure. This tubing is used for piping of services and in structural applications. Tubing for boilers and similar uses is constructed from high-grade open-hearth steel, and is cold-bent by a train of rolls, the edges being joined by the electric-resistance weld process. Seamless tubing is produced in the plug mill, in which round bar is rolled down to the required diameter; this is extensively used in the oil industry.

In the time available it was inevitable that some sections should be omitted, but much interesting information was provided on the coke-oven plant and its by-products, the sintering of fine ore for presentation to the blast furnace and production of oxygen for the Bessemer plant.

After tea, Mr A. J. Turnbull conveyed the thanks of members to the company and all those individually concerned for a most instructive visit, and for hospitality at lunch and tea. Mr Chilton, of the training department, which was responsible for making the arrangements, responded.

Royal Greenwich Observatory. Members visited the Royal Greenwich Observatory at Herstmonceux Castle on 20 June.

The Observatory was established by Charles II in 1675 at Greenwich to provide astronomical data for navigational purposes. H.M. Nautical Almanac Office is a branch of the Observatory. The choice, by international agreement, of the meridian through the transit circle of the Royal Observatory at Greenwich as the prime or zero meridian was in fact a recognition of the important contributions by the Observatory to the astronomical and nautical sciences.

The growth of London and the consequent deterioration in conditions for observation led to the removal of the Observatory from Greenwich to its present rural setting at Herstmonceux Castle, near Hailsham, Sussex. The move was completed in 1958.

The Castle was built in 1440, but only the original walls remain as one of the earliest examples of brick-built structures. The interior was completely rebuilt

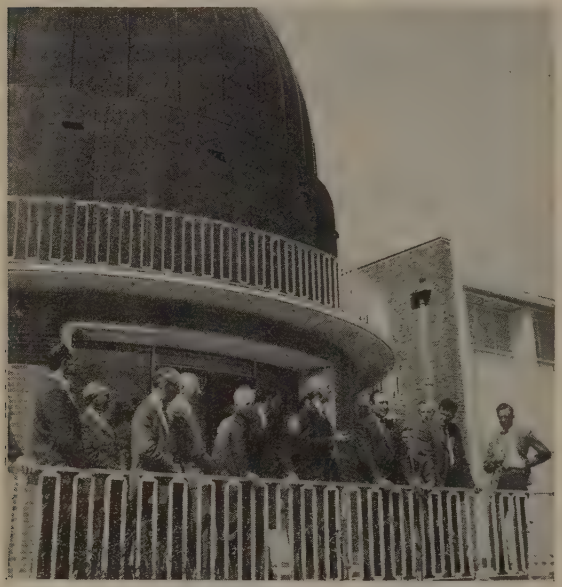
The South Gate of Herstmonceux Castle—a part of the original walls

early in this century and now houses part of the Observatory administration and services. The grounds

contain a number of domes which house the various telescopes and equipment.

The party was met by Dr A. Hunter, who acted as guide and explained the significance of the equipment.

In the time section the old and the new were seen: the pendulum clock made by John Harrison 200 years ago, and the quartz crystal 'clocks' which are used to relay time signals not only to other equipment used at the Observatory but also to the B.B.C., the G.P.O. and other stations needing an accurate timing check. The signals are accurate to about 2 to 3 milliseconds. It is likely that in the not-too-distant future the definition



Dr Hunter (*centre*) talks to members below one of the Equatorial Domes

of the second will be based on purely physical data rather than on the rotation of the earth.

The Observatory is also responsible for the servicing, checking and repairing of all timepieces used by the Navy and many of those used by the Army and Air Force.

The party then visited the meridian group, where work was being carried out on the transit circle and observation was possible over an arc of sky of nearly 170°. The way in which the telescope was set up in correct position and alignment was described. Information about the transit of a star, correct to 0·01 sec of arc and 0·001 sec of time, is fed on to a punched card which can then be processed in an electronic computer.

In the equatorial group the party saw a 36-in reflecting telescope used for photographing the spectra of stars. The mirrors were aluminized, not silvered, and the group operates its own aluminizing plant. A 26-in refracting telescope used for measuring the distance of stars was next seen. In this dome, the whole floor could be raised on jacks to elevate the observer to the best position for viewing. Over 1,500 photographs per year are taken to measure stellar parallax. A 28-in refracting telescope housed in another dome of this group was used for the visual examination of double stars. Such stars are so close together in the sky that photographic methods cannot be used. Only visual examination can yield the necessary measurements, which result in estimation of stellar mass.

During the tour and again at the end, Dr Hunter answered many questions. In thanking the Astronomer Royal for granting the facilities for the visit, Mr Alwyn Jones made especial mention of the part played by Dr Hunter in making the visit such an outstanding success.

Road Research Laboratories. On 23 June a group of members visited the Road Research Laboratories at Harmondsworth, West Drayton, Middlesex. The party was welcomed on behalf of the director by Mr D. H. Mathews, who outlined the wide scope of investigations carried out in the laboratories of the materials and construction division at Harmondsworth, and described the activities of the other sections of the station.

The party was conducted through the sections dealing with investigations into bituminous materials, concrete, soils and special problems. In each section senior members of staff gave stimulating accounts of their work, which were excellently illustrated by charts, equipment and exhibits.

It was very interesting to see the important part which chemistry played in these studies, and pleasing to learn of Britain's pre-eminence in the science and technology of road construction. The interest created was evident from the number of questions which arose during the discussions; the vote of thanks to the director and the staff was proposed by Dr R. M. Evans.

B.B.C. Television Centre. On 29 June a party of members were taken on a conducted tour of the new B.B.C. Television Centre at Shepherd's Bush. After a general view of the Centre, the party saw camera rehearsals in progress for the shows 'Magnolia Street' and 'Music for You.' Members also visited control rooms, scenery workshops, art studios and property stores.

CEYLON

Morphology of 'Trigonopsis Variabilis.' A joint meeting with the Chemical Society of Ceylon was held on 10 May at the University of Ceylon, Colombo. Dr S. Senthe Shanmuganathan, research officer of the Medical Research Institute, Colombo, a former research fellow at the Waksman Institute of Microbiology, New Brunswick, U.S.A., spoke on 'The Biochemical Interpretation

of the Morphology of the Triangular Yeast *Trigonopsis variabilis*.' Dr Shanmuganathan said that nutritional conditions could affect the form of growth of yeast-like organisms. Attempts to elucidate causal relations among nutritional factors—biochemical mediation—were of recent date. The speaker referred to studies on three different yeast-like organisms as an illustration of such attempts, and dealt in detail with the yeast *Trigonopsis variabilis*. He said that the triangular yeast could be grown in a purely 'ellipsoidal' form, or a purely triangular form. The nutritional factor governing control of form seemed to be the availability of a methyl group. The relations of choline synthesis, phospholipid synthesis and cellular form were also discussed. The analysis of whole cells and cell walls of both forms of the yeast indicated that there was a preponderance of lipids and phospholipids in whole cells and cell walls of the triangular form, as compared with the ellipsoidal forms. Experimental evidence in support of this hypothesis involving the use of methyl-^{14}C-methionine was also discussed. Dr George Ponnamperuma, President of the Chemical Society of Ceylon, who presided, proposed the vote of thanks to Dr Shanmuganathan.

Beach Sands. At a joint meeting with the Chemical Society of Ceylon, held on 25 May at the University of Ceylon, Mr P. Wiswanathan, of the Government Mineral Sands Corporation, Pulmoddai, spoke on 'Beach Sands.' Mr Wiswanathan, an Indian, who had first served in Burma and then in the Travancore Mineral Works, India, gave a very interesting historical account of how the minerals in beach sands came to be exploited. He said that beach sands at Pulmoddai, on the north-east coast of the island south of the Kokillai Lake, had the highest recorded percentage of ilmenite, and were superior in this respect to Indian and Australian sands. He then gave a brief account of how ilmenite, rutile, zircon and monazite are separated from the sands. He stressed the importance of Ceylon monazite, which, he said, contained 8–9 per cent thorium. Mr Wiswanathan then answered many questions on the work of the Mineral Sands Corporation. Mr Noel Jayatunge, Section Chairman, who presided, proposed the vote of thanks to Mr Wiswanathan.

Tea Manufacture. At a joint meeting with the Chemical Society of Ceylon held on 2 June at the University of Ceylon, Dr Ponnamperuma presided. He introduced Dr D. L. Gunn, C.B.E., director of the Tea Research Institute, Talawakelle, Ceylon, whose subject was '*Quo Vadis*—Where next in Tea Manufacture?' Dr Gunn began his talk with a brief outline of the economy of the island, pointing out how it was so inextricably linked with the tea industry, and how the tea industry in turn felt the impact of the changes in the island's fortunes. He then summarized the various processes involved in the manufacture of tea, and indicated the lines of research that would help acquire a wider market for Ceylon's tea. In particular he mentioned that 'soluble tea,' perfected jointly by the Ceylon Institute for Scientific and Industrial Research in Colombo and the Tea Research Institute in Talwakelle, was made from the green leaf and consequently was superior to the product on the American market which was made from the processed leaf. He said that there was a definite future for the Ceylon soluble tea in the markets of the U.S.A. Roberts in the United Kingdom had done considerable work on the polyphenols of tea, and Dr Gunn hoped that as a result there might some day appear a more reliable alternative to the 'tea taster.' The techniques of gas chromatography might conceivably be used to study the volatile components of tea responsible for the aroma of brewed tea. Dr Gunn then answered the many questions asked by members, frequently calling upon Mr Ramasamy, biochemist of the Tea Research Institute, to join in the discussions. Dr M. U. S. Sultanbawa asked Dr Gunn why the tea trade, and the Tea Research Institute in particular, had offered no help in the form of grants to the University of Ceylon for research on projects connected with the biochemistry of tea. Dr Gunn replied that the finances of the T.R.I. did not permit such grants to be offered. But postdoctoral fellowships were available to those willing to devote a protracted period of time to tea research, and for these the T.R.I. would be willing to offer training facilities in the United Kingdom. Dr Ponnamperuma proposed the vote of thanks to Dr Gunn.

DECCAN

Works Visit. On 27 May a party of members and guests paid a very enjoyable visit to the Mysore Industrial and Testing Laboratory Ltd, Malleswaram, Bangalore. The party was welcomed by Mr V. Venugopal Naidu, the managing director, who said that the institution was founded in 1931 with the object of manufacturing the pharmaceutical requirements of the several government departments, investigating the industrial problems of the State and testing government purchases. He then gave a historical survey of the development of the organization. Mr S. G. Sastry, the general manager, gave a brief account of the current activities of the laboratory.

After coffee kindly provided by the hosts, the visitors, divided into small groups, were taken round different departments and shown the manufacturing processes. The members of the staff took keen interest in explaining the work.

Dr B. H. Iyer, Chairman of the Section, expressed the thanks of the party for a most interesting afternoon.

MADRAS

Film evening. On 22 June members and guests attended a film show by courtesy of the United States Information Service at their Little Theatre. The

following films were shown: 'Survey of Astronautics'; 'Project Mercury'; and 'World Watches Experiment in Space'. These three films depicted man's quest to probe the mysteries of outer space and showed America's first astronaut in his journey and return from outer space.

Mr K. S. S. Varadan proposed the vote of thanks.

The Training of Chemists. On 8 July a well-attended symposium on 'The Training of Chemists' was inaugurated at the Madras Medical College by Mr R. Venkataraman, Minister for Industries and Labour, Government of Madras. The Minister, in his speech, dealt

Mr R. Venkataraman inaugurating the symposium

with the prospects of increased activity in India in the chemical and allied industries during the third plan period. The production of nitrogenous and phosphatic fertilizers is to be stepped up. The production of heavy chemicals such as sulphuric acid, caustic soda and soda ash will also be increased. The growth of the chemical industries would afford tremendous opportunities to chemists and chemical engineers.

Dr S. V. Anantakrishnan, Professor of Chemistry, Madras Christian College, spoke on 'Teaching and Research'. He stressed the need for teaching more mathematics to chemistry students. Textbooks provided for students are not satisfactory. The analytical technique taught in the colleges should include some of the more modern methods.

Mr K. V. Sundaram Ayyar, formerly Government Analyst, Madras, spoke on 'The Public Analyst'. He dealt with the qualifications necessary for the public analyst and stressed the need to organize a professional organization of public analysts in India.

Dr A. R. Natarajan, Director, State Forensic Science Laboratory, gave an account of the training that is provided for forensic scientists in his Laboratory. There are about 13 sections in this organization; there is a programme to cover some essential sections in a short-term training, and a long-term training gives opportunity for the trainee to get acquainted with all the sections.

Dr Ninan Verghese, Professor of Biochemistry, Madras Medical College, spoke on 'Clinical Chemists'. He said that the facilities of a clinical chemistry laboratory should be available at district level in this State, and these laboratories should have a fully-qualified clinical chemist.

Mr S. Ramaswamy, of the Mettur Chemical and Industrial Corporation, speaking on 'Industrial Chemists', stressed the need for careful revision of curricula of the colleges, taking into consideration the needs of the industries. Mr K. S. S. Varadan, Professor of Pharmaceutical Chemistry, Madras Medical College, spoke on 'Pharmaceutical Chemists'.

Dr K. S. G. Doss, Director of the Central Electrochemical Research Institute, who presided over the symposium, stated that more educational opportunities are needed. Other institutions besides universities should be recognized for the award of degrees. A proper language policy in the country is imperative.

Mr N. Pitchandi proposed the vote of thanks.

East Africa

Taints in Tea. On 5 April members and friends gathered at the Royal College, Nairobi, to hear a lecture by Dr R. Child on 'Taints in Tea and their Prevention.' Dr Child was the first Chairman of the Section, and as this was his last appearance before retiring, the occasion was taken to express members' thanks for all his hard work on behalf of the Section, and good wishes for his new life in England.

Taints in tea may arise from causes connected with growing, processing, storing or packing, and the cause is often not easy to track down. Difficulties with the growing tea are due almost entirely to the use of insecticides, and the synthetic chlorinated compounds are particularly troublesome. An example of this trouble occurred in August, 1954, when a considerable area of tea in the Limuru district was sprayed from the air with benzene hexachloride in the course of locust control operations. As a result, two or three plucking rounds (about one month's crop) were quite unsaleable.

Lack of hygiene during processing can quickly result in growth of micro-organisms that seriously affect the taste. The rate of drying is also critical, too slow a rate giving a 'stewed' tea and over-firing a 'bakey' tea. Even during sorting and packing there is a possibility of taints being picked up. On one occasion in 1953 the fault could have arisen only in the sorting room, but there was no evidence of anything wrong. It was finally shown that some vapour given off by 'fungus gardens' in termite galleries under the packing floor had entered through drill holes made to bolt new machinery in position.

Further problems are met in storage and packing, and it has been disappointing to find that polythene, so generally suitable, allows loss of volatile flavouring substances when tea is stored in it for long periods.

Discussion and questions followed this lecture, after which Dr E. W. Russell, director of the East African Agriculture and Forestry Research Organisation, proposed the vote of thanks to the lecturer.

News and Notes

AWARDS AND COURSES

Chemical Society Research Fund.—The Research Fund of the Chemical Society provides grants for the assistance of research in all branches of chemistry. Applications for grants will be considered in November, and should be submitted on the appropriate form not later than 15 November. Application forms, together with regulations governing the award of grants, may be obtained from the General Secretary, Burlington House, Piccadilly, London, W.1.

Nuclear Studies.—A series of postgraduate full-time courses in nuclear science is to be held in the Nuclear Studies Section of the Department of Chemistry and Biology, Liverpool College of Technology, during the 1961–62 session. A one-week course in radiation chemistry will be held on 18–22 June, 1962 (fee £5), and two two-week courses on radiochemistry (fee £12 each) have been arranged. The first will take place on 16–27 October and the second at a date in 1962 still to be fixed. Other courses include those on radiation safety and health physics (four two-week courses and a seven-month course) and radiobiology (three two-week courses). Further details may be obtained from Mr J. W. Lucas, organizer of nuclear studies, New Building, Byrom Street, Liverpool, 13.

Summer School on Corrosion.—The Metallurgy Department of the Battersea College of Technology has, in conjunction with the Corrosion Group of the S.C.I., arranged the Eighth Summer School on Corrosion, entitled 'Corrosion Problems in the Electrical Power Industry'. It will take place on 25–28 September. The fee is £10. Enrolment forms may be obtained from the Secretary (Summer School), Battersea College of Technology, London, S.W.11.

MEETINGS AND CONFERENCES

Chemical Documentation.—A Symposium on scientific and technical documentation and information in chemistry is to be held at the Casa delle Associazioni Scientifiche e Tecniche, 10 Via del Politecnico, Milan, on 9–10 November under the auspices of IUPAC and the Federation of Scientific and Technical Associations of Milan, and is being organized with the co-operation of the Centre Français d'Échanges et de Documentation Techniques. The provisional programme is divided into four sections; publication of documents; centres for documentation and information; current and retrospective bibliographies; and automation in research for information. Participation is by invitation only, with the exception of the inaugural meeting, which will be public. Further details may be obtained from the Secretary of the Meeting, Dr Luigi Satta, c/o Soc. Montecatini, Largo Guido Donegani 1/2, Milan.

Chemical Society Symposium.—A Symposium on 'Electron Spin Resonance' will be held at Queen Mary College on 2 November at 2 p.m. The provisional list of speakers includes Professors D. J. E. Ingram, H. C. Longuet-Higgins, F.R.S., M. C. R. Symons and S. I. Weissmann, and Drs J. R. Bolton, A. Carrington, E. A. C. Lucken and J. R. Morton.

Corrosion in the Nuclear Energy Industry.—A Symposium on this topic will be held at the Maison de la Chimie, Paris, on 19–20 October. It is organized by the Société de Chimie Industrielle, and the President of Honour is M. F. Perrin, High Commissioner for Atomic Energy. The programme is particularly concerned with corrosion in sheath materials. It forms the 16th event arranged by the European Federation of Corrosion. Application forms, which should be returned not later than 2 October, may be obtained from the Société de Chimie Industrielle, 28 rue Saint-Dominique, Paris 7e, France.

Faraday Society.—The Society is holding a general discussion on 'The Structure and Properties of Ionic Melts' on 5–7 September at the Department of Inorganic and Physical Chemistry, University of Liverpool. The conference fee is £3 for non-members of the Society. There will be four sections; structure and spectra, cryoscopy; thermodynamics; and transport properties. Further details may be obtained from the Assistant Secretary, 6 Gray's Inn Square, London, W.C.1.

Imperfections in Crystals.—The Institute of Physics and the Physical Society announces that the Autumn Conference of its X-ray Analysis Group on this topic will be held on 17–18 November at the Institution of Mechanical Engineers. The three sessions of the Conference will be devoted to the nature of crystal imperfections and of associated diffraction effects; experimental methods for studying imperfections; and their influence on the physical properties of crystals. Invited speakers include Professor F. C. Frank, O.B.E., and Dr P. B. Hirsch. Correspondence regarding the programme should be addressed to the Honorary Conference Secretary, Dr G. S. Parry, Department of Chemical Engineering, Imperial College of Science and Technology, Prince Consort Road, London, S.W.7; that regarding attendance should be addressed to the Administration Assistant, The Institute of Physics and the Physical Society, 47 Belgrave Square, S.W.1.

International Society for Fat Research.—Dr E. G. Woodroffe, director in charge of research, Unilever Ltd, has been chosen as President of the Sixth I.S.F. Congress, following the death of Dr T. Malkin. The

Congress is to be held in London on 9–13 April, 1962. It is expected that some 60 papers relating to original work in the oils and fats fields will be presented. These lectures will be given in the Physics Building of the Imperial College of Science and Technology, by courtesy of the Governing Body and Rector. Application forms for provisional registration and submission of papers may be obtained from the Congress Secretaries, Drs F. Bradley and H. Jasperson, 14 Belgrave Square, London, S.W.1.

Non-Stoichiometric Compounds.—The Inorganic Chemistry Section of the American Chemical Society will hold a Symposium on this topic at the Spring Meeting of 1962. This meeting is to take place in Washington, D.C., on 20–29 March, 1962. The Symposium will be divided into three sections, hydride systems, oxide systems, and chalkogenides and miscellaneous systems. Manuscripts of papers should be submitted to the chairman of the Symposium, Roland Ward, Esq., University of Connecticut, Storrs, Connecticut, by 9 November. It is expected that the papers presented will be published in one volume.

Physics of Space Research.—The Institute of Physics and the Physical Society is organizing a residential symposium on 'Some Aspects of the Physics of Space Research' to be held at the Royal Military College of Science, Shrivenham, Wiltshire, on 20–22 September. The subjects to be discussed are: the advantages to physicists of space research; cosmic rays, particle physics and meteorology; radio research from rockets and satellites; and rockets, orbits and trajectories. Further details may be obtained from the Administration Assistant of the Institute of Physics and the Physical Society, 47 Belgrave Square, S.W.1.

Society of Dyers and Colourists.—The Society is holding a Symposium on 'Science and Craft in both Textile and Non-Textile Coloration' at Bristol on 20–22 September.

The 16th Mercer Lecture will be given by Dr J. L. Bolland in the Banqueting Hall, Midland Hotel, Manchester, on 8 November at 7.30 p.m. The title of the lecture is 'Bleaching of Cotton'. Further details of these events may be obtained from the General Secretary of the Society, Dean House, 19 Piccadilly, Bradford 1, Yorkshire.

Symposium on Spectroscopy.—The Hydrocarbon Research Group of the Institute of Petroleum will hold its third Symposium on Spectroscopy in the William Beveridge Hall of the University of London on 28–31 March, 1962. It will be similar to those held in 1954 and 1958, and will review progress in many spectroscopic fields, including infra-red and Raman spectroscopy; nuclear and electron-spin resonance; spectra of free radicals; vacuum ultra-violet spectra and ionization potentials; and X-ray fluorescence and atomic absorption spectra. Applications for attendance and for further details should be sent to the General Secretary, Institute of Petroleum, 61 New Cavendish Street, London, W.1.

New National College.—A National College of Agricultural Engineering has been established, and will open in the autumn of 1962 in temporary premises made available by the Ford Motor Co. at Boreham, near Chelmsford, pending the completion of its own premises at Silsoe, Bedfordshire, which will be ready for occupation the following year. The first Principal of the new College will be Dr P. C. J. Payne, lecturer in agricultural engineering, University of Durham. The college will be fully residential and will accommodate between 60 and 100 students.

The main course at the college will lead to the award of a College Diploma, and will prepare for work in agricultural engineering at professional level. The course will require three years' full-time study, and candidates for entry will need qualifications roughly equivalent to those required for a degree course in engineering. It is also intended to provide shorter courses of an advanced type for students who have already obtained a degree or equivalent qualification in engineering or agriculture.

News from I.C.I.—The Soviet Minister of Foreign Trade, Nikolai S. Patolichev, who opened the Russian Exhibition in London on 7 July, visited the headquarters of Imperial Chemical Industries Ltd, Plastics Division, Welwyn Garden City, on 10 July at his own request. I.C.I.'s sales last year to the U.S.S.R. and Eastern Europe totalled £5,500,000.

Mr N. S. Patolichev (*hand on chin*) is seen here in the I.C.I. Plastics Division research laboratories. His interpreter (*left*) is putting a question to Dr J. W. C. Crawford, research manager

I.C.I. has decided to build two plants, with a capital investment of approximately £½ m., in Western Nigeria to manufacture paints and plant protection products. It is hoped that the plants will be on the site of the Ikeja Industrial Estate outside Lagos. This will be I.C.I.'s first manufacturing venture in Nigeria.

CORRESPONDENCE

Reporting of Results

Sir,—A guide to authors wishing to state the reliability of their results has recently been published.[1] Although the recommendations apply only to one American Chemical Society journal at present, there may be a tendency for authors to use the terms in British publications. Before this happens, it would be worth while to examine critically the recommended terms, which have been agreed by chemists and statisticians in the United States. The agreement seems to be premature and may not be found on this side of the Atlantic. There is already considerable confusion in the minds of chemists over the term 'error' when used by statisticians. The suggestion that this term should be used only when 'accuracy' or systematic error is being discussed seems very dangerous. (What about the term 'standard error'?) I would like to see 'error' used as little as possible. In particular, the terms 'mean error' and 'relative error' (*see* Table) are probably not even necessary.

Table: Accuracy Data[1]

(Measurements which relate to the difference between the average test results and the true result when the latter is known or assumed.) The following measures apply:

Mean Error	The average difference with regard to sign of the test results from the true results. Also equal to the difference between the average of a series of test results and the true result.	$\mu - \bar{x}$
Relative Error	The mean error of a series of test results as a percentage of the true result.	$\frac{100\ (\mu - \bar{x})}{\mu}$

A statement of the experimentally determined mean ($\bar{x}$) and standard deviation (s) of a set (n) of results will enable the reader to decide whether $\bar{x}$ differs from the true mean (μ). If there is evidence of a bias it is better to say so explicitly. If not, it is confusing to use the term 'mean error'. The danger lies in considering mean error to be an absolute measure because it is associated with the term 'accuracy'; the fact that it is an estimate of the true systematic error (bias) with an associated precision (random error) may easily be forgotten.

B. J. Walby

The Distillers Co. Ltd,
Development Division,
Research Department,
Great Burgh,
Epsom, Surrey

Reference

1. *Analyt. Chem.*, 1961, **33**, 480.

The Mole in Electrochemistry

Sir,—The account of the Symposium on the Teaching of Inorganic Chemistry at Pre-University Level says[1] that, in several written contributions received, the widespread use of equivalents in electrochemistry (conductances, Faraday's laws and the like) was pointed out, apparently to support the retention of 'equivalent' in teaching. Following the publication of my letter showing the superfluity of 'equivalent',[2] Professor E. A. Guggenheim was kind enough to write to me: 'I hope that you will enlarge your recommendations so as to cover electrochemistry. . . .'

I therefore offer some remarks concerning the displacement of 'equivalent' by mole in electrochemistry. Equation (6) is just another member of the set of related controversial equations of which I have already given five examples[2]:

$$\text{molar (or proper}^3\text{)} \quad \text{conductance} = z \times \text{'equivalent conductance'} \qquad (6)$$

As I said before of this set,[2] a formula must be quoted for complete clarity, and so molar conductance suffices and 'equivalent conductance' is superfluous. Consideration of the following examples, which are taken from Professor Guggenheim's letter:

$$\Lambda\,(Mg^{2+}) = 106\ \Omega^{-1}\ cm^2\ mole^{-1},$$

$$\Lambda\,(\tfrac{1}{2}Mg^{2+}) = 53\ \Omega^{-1}\ cm^2\ mole^{-1},$$

$$\Lambda\,(Cl^-) = 76\ \Omega^{-1}\ cm^2\ mole^{-1},$$

$$\Lambda\,(\tfrac{1}{2}MgCl_2) = \Lambda\,(\tfrac{1}{2}Mg^{2+}) + \Lambda\,(Cl^-) = 129\ \Omega^{-1}\ cm^2\ mole^{-1},$$

$$\Lambda\,(MgCl_2) = \Lambda\,(Mg^{2+}) + 2\Lambda\,(Cl^-) = 258\ \Omega^{-1}\ cm^2\ mole^{-1},$$

leaves no doubt, in any instance, as to what a mole signifies.

Faraday's laws can be expressed in terms of the mole concept by means of the equation:

$$Q = znF \quad .. \quad .. \quad .. \qquad (7)$$

Here $n = w/M$ is the molar (or proper) amount[4] of an electrolyte $(R^{z/\omega_+}_{\nu_+/\omega_+})_{\omega_+}(X^{-z/\omega_-}_{\nu_-/\omega_-})_{\omega_-}$, where z, ω_+, ω_-, ν_+, ν_-, ν_+/ω_+, ν_-/ω_-, z/ω_+ are positive integers, of which ω_+ and ω_- are relatively prime and at least one is usually, but not always, equal to unity, $-z/\omega_-$ is

a negative integer, and M is the molar (or proper) mass of the electrolyte. Q is the quantity of electricity involved in the electrochemical reaction of a mass w of the electrolyte. ***F***, the Faraday constant, is the least quantity of electricity ever observed to be involved in the electrochemical reaction of one mole of any electrolyte $(R_{+/\omega_+}^{z/\omega_+})_{\omega_+}(X_{\nu_-/\omega_-}^{-z/\omega_-})_{\omega_-}$. This characterization of ***F***, in the form of what may be called a minimole of electricity, is really an application of Cannizzaro's greatest common divisor principle[5] for obtaining minimolar masses ('gram atomic weights') of elements.[6]

The foregoing concise account of Faraday's laws is a molar account which would remain valid though atoms and molecules had not been discovered. Students should learn both the molar approach and the molecular approach and the relationships between them.[6] In neither approach is the 'equivalent concept' needed and, indeed, its use may obscure the fact that in both approaches the novel and important features are the electrovalences (or charge numbers) z/ω_+ and $-z/\omega_-$ and the Faraday constant, ***F***.

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5. S. Cannizzaro, *Sketch of a Course of Chemical Philosophy*, Alembic Club Reprint No. 18, 1910, 11; James Thin, Edinburgh.
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NORMALITY AND THE PERIODIC SYSTEM

Normality

Twenty-five years ago my pupils asked what was the use of learning about normality. Since then, I have often asked myself the same thing. Consequently, I rejoice to hear that others are asking the same question. May the winds of change blow into a howling gale, and sweep away some of this lumber along with phlogiston, the archeus and the crith!

The Periodic System

As against the extremely early use of the periodic system in a grammar school, one should bear in mind:—

(*a*) Without a modicum of facts the names in the periodic system will be meaningless, and the periodic system itself unappreciated;

(*b*) Most pupils need a smattering of chemistry (as they need mathematics) as a stepping-stone leading to other work. They need familiarity with common substances. Many of these pupils are our less able ones. To them the generality known as the periodic system may or may not be of some slight help;

(*c*) The historical method is often a good general guide to procedure in teaching. It points to the use of the periodic system AFTER a considerable knowledge of facts has been gained. Then the need for a generalization is felt;

(*d*) To lead up to the periodic system gradually is an excellent example of the method of induction —one of the most important methods in the philosophy of science.

Some of my biological colleagues try to teach classification to young children before pupils have enough knowledge to see the need for it. The pupils find the unfamiliar words bewildering.

But by all means use the periodic system as soon as you feasibly—not forcibly—can.

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CHEMICAL EQUIVALENTS

SIR,—If we are to dispense with the concept of equivalents in chemistry, it is necessary to know (or to agree upon) the chemical formulae of compounds. Historically, the concept of equivalent gained importance at a time when chemists could not agree upon formulae. Those of us who sat at the feet of chemists of the old school learned to regard the equivalent as 'fundamental' because it could be determined experimentally, whereas chemical formulae could only be inferred. This is, of course, no good reason for now so regarding it, but there are occasions when the concept is very useful.

In polymer chemistry (my own preoccupation) we have often no means of knowing the 'chemical formula' and it is useful to be able to refer to an equivalent as the weight associated with a monofunctional group (*e.g.* epoxide, hydroxyl, or isocyanate equivalent). It should be noted that molecular weight is neither arbitrary nor 'redundant' in polymer chemistry but is often unknown. Much the same situation arises whenever new compounds are being studied.

It is perhaps noteworthy that the urge to eliminate equivalents comes largely from those concerned with the study of highly-ionized electrovalent substances (*i.e.* inorganic chemistry at pre-university level!) for whom 'molecular weight' has no great significance. Perhaps it is a pity that the study of chemistry has to begin in this rather narrow and specialized field.

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OBITUARY

Baron McGowan of Ardeer

Harry Duncan McGowan was born in Glasgow on 3 June, 1874, and died in St Mary's Hospital, Paddington, on 14 July, aged 88.

After attending Allan Glen's School he began his working life in about 1888 as a junior clerk at Nobel's Explosives Co. in Glasgow, and 'extended the ladder above him as he rose'. With Sir Alfred Mond (Lord Melchett) he forged Imperial Chemical Industries in 1926 by the merging of four companies, and this did much to enable the U.K. to compete with the great and justly famous chemical combines of Germany and the U.S.A. He had already shown the advantages of reorganization in the formation of Canadian Explosives Ltd by amalgamation of the major companies active in that field. Its interests then rapidly expanded and it became Canadian Industries Ltd in 1927. A similar merger in this country had resulted in the formation of Nobel Industries Ltd in 1918, and in South Africa a similar development led to the formation of the group now known as African Explosives and Chemical Industries Ltd. His activities also spread to the Continent, Australasia and South America.

On the formation of I.C.I., Sir Harry McGowan (K.B.E. 1918) became president and deputy chairman, succeeding Lord Melchett as chairman when the latter died in 1930. He was created first Baron McGowan in 1937. He remained in office until the end of 1950, having seen I.C.I. emerge from World War II as a company of world renown.

As Sir Harry McGowan he was President of the Society of Chemical Industry in 1931. He received honorary degrees from the universities of Glasgow and Birmingham (1934), Oxford (1935), Durham (1949) and St Andrews (1950), and from 1934 to 1939 he was Hon. Colonel of the 52nd (Lowland) Divisional Signals, Royal Corps of Signals. In 1952 he was among the first to be elected to Honorary Fellowship of the Institute.

Walter George Bailey. *B.* 30.8.1898. *Ed.* University of Edinburgh, 1915–17, 1920–22 (interrupted by war service). B.Sc. He continued for a further year as a research student at the University, and in 1923 was appointed an assistant chemist at Nobel's Explosives Co. Ltd (now Imperial Chemical Industries Ltd, Nobel Division). He later became chemist in charge, central analytical laboratories, and during the second world war was engaged as assistant works manager, Ministry of Supply Factory, Grangetown, Girvan. At the close of hostilities he returned to Imperial Chemical Industries Ltd and later became works manager at the Ministry of Supply Factory, Bowhouse, a position which he held until his retirement in 1959. (*A.* 1923, *F.* 1944) *D.* 15.3.61.

Cecil William Dannatt. *B.* 2.8.1892. *Ed.* Colfe's Grammar School; Royal School of Mines, London, 1910–14. In August, 1914, he enlisted in the Queen's Westminster Rifles, received a commission the following year, and served in France, Salonika and Palestine. On being demobilized in 1918, he joined the Ministry of the Interior, Cairo, as assistant director of the technical section, Public Security Department. Two years later he went to Trinidad as assistant geologist to Naparima Oilfields Ltd. In 1923 he returned to the Royal School of Mines to work as a research student in the metallurgy department. He joined the teaching staff of the department a few months later and remained for 34 years, first as demonstrator, then as lecturer, reader, acting director and finally, from 1945 until his retirement in 1957, as professor and head of the department. Shortly after his retirement, the title of Professor Emeritus of Metallurgy was conferred upon him by the University of London and in 1960 he became a Fellow of the Imperial College. 'Professor Dannatt had a charming and gracious personality, and he was an unsparing worker. He was always anxious to help and always reluctant to refuse any request for advice or information, or demand for his services.' (*F.* 1936) *D.* 9.4.61.

Robert Edward Dodd. *B.* 14.5.25. *Ed.* St Peter's School, York; Trinity College, Oxford. M.A., B.Sc. In 1946 he was appointed a lecturer in chemistry at King's College, Newcastle upon Tyne, a post which he held for the rest of his life. He was granted a year's leave of absence in 1952–53 on being awarded a postdoctorate fellowship of the National Research Council of Canada. He was the author, or joint author, of a number of scientific papers and for several years served as the honorary representative of the Institute at the College where he was engaged. (*A.* 1947, *F.* 1958) *D.* 25.2.61.

Albert Edmund Fletcher. *B.* 23.12.01. *Ed.* Liverpool Central Technical School, 1916–22. He joined the English Margarine Works Ltd as assistant analyst in 1916, and subsequently became senior analyst and then chief analyst. He left in 1930 to take a post as assistant analyst and bacteriologist to the Somerset County Council. He left this country in 1937 on his appointment as chief analyst to the Shanghai Municipal Council. He resigned in 1940, and on his return to this country was for a time chief chemist to Trafford Oil Mills, Manchester, before joining H.M. Forces. He served in Rangoon prior to his release in 1948, when he joined Ward, Blenkinsop & Co. Ltd as chief analyst at their Halebank factory, a position which he held for the remainder of his life. He was a great sportsman and a keen follower of Rugby football, and was for many years a member of the Wigan Club and later of the Liverpool Rugby Union Football Club. His main hobby was philately. 'His jovial personality and sense of humour made him very popular both at his place of employment and amongst his many friends in all walks of life.' (*A.* 1924, *F.* 1931) *D.* 27.1.61.

Clarence Jepson. *B.* 22.5.1889. *Ed.* Glossop Grammar School; University of Manchester, 1907–10. M.Sc. He became a senior assistant chemist at the Manchester Corporation Sewage Works until the first world war, when he was engaged in H.M. Factory, Sutton Oak, and later at the Research Department, Royal Arsenal, Woolwich. Immediately after the Armistice, he returned to Manchester as resident chemist in the Rivers Department of the Corporation. He remained there until his retirement in 1954, when he was general manager. He was the author of papers in the scientific press. (*A.* 1918, *F.* 1937) *D.* 12.4.61.

John Douglas Robertson. *B.* 30.6.03. *Ed.* Universities of St Andrews and London. D.Sc., M.D. (St And.), Ph.D., Ch.B. (Lond.). In 1928 he took an appointment on the staff of the Courtauld Institute of Biochemistry, Middlesex Hospital, until 1947, when he was appointed director of the department of clinical investigation at the London Clinic. He left in 1954 to set up a practice in Harley Street. He was the author of many papers. (*F.* 1945) *D.* 14.3.61.

THE REGISTER

NEW FELLOWS

Din, Badar-Ud, M.SC., PH.D.(LAHORE)
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(P) Hunter, Donald Noel
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(N) DEWAR, James Hilton
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(P) BAGCHI, Sankar Prosad
(EE) EILBECK, William John, B.SC.(WALES)
(C) EVANS, Doreen Margaret, B.SC.(LEEDS)

DEATHS

Honorary Fellow

MCGOWAN, Harry Duncan, first Baron McGowan of Ardeer, K.B.E., D.C.L., LL.D. Died 13 July, 1961, aged 87.

Fellows

(F) ANDREWS, John, B.SC.(LOND.). Died 1 July, 1961, aged 76. *A.* 1918, *F.* 1922.
(P) COATES, Arnold Coulson, B.SC.(LOND.). Died 29 April, 1961, aged 58. *A.* 1935, *F.* 1938.
(Q) COULTHARD, Albert, B.SC.(MANC.), PH.D.(FREIBURG). Died 15 July, 1961, aged 85. *F.* 1920.
(K) DALLAS, William. Died 30 June, 1961, aged 76. *A.* 1923, *F.* 1929.
(K) HILL, John Whitelaw. Died 27 June, 1961, aged 81. *A.* 1921, *F.* 1929.
(R) PETERS, William Harold. Died 10 May, 1961, aged 81. *A.* 1902, *F.* 1905.
(H) RULE, Tom Edgar. Died 12 January, 1961, aged 73. *A.* 1940, *F.* 1943.
(N) STYAN, George Eric, B.SC.(LOND.). Died 5 July, 1961, aged 50. *A.* 1941, *F.* 1960.
(P) TAYLOR, Edward Albert, B.SC.(LOND.). Died 31 May, 1961, aged 53. *A.* 1930, *F.* 1947.
(P) VOSS, Walter Arthur. Died 4 July, 1961, aged 63. *A.* 1919, *F.* 1943.
(P) WALLER, Arthur William. Died 20 June, 1961, aged 60. *A.* 1931, *F.* 1945.
(D) WILSON, John, M.SC.(MANC.). Died 1 July, 1961, aged 88. *F.* 1909.
(Q) WOOD, John Kerfoot, D.SC.(MANC.). Died 1 July, 1961, aged 84. *F.* 1919.

Associates

(D) BAXTER, Arthur Edward. Died 16 June, 1961, aged 63. *A.* 1946.
(Q) CHAPMAN, Ernest, M.SC., PH.D.(MANC.). Died 22 February, 1961, aged 63. *A.* 1921.
(Q) CLAYTON, Joseph. Died 27 June, 1961, aged 37. *A.* 1949.
(P) HAMMOND, Edmond, B.SC.(LOND.), PH.D.(SHEFF.). Died 4 July, 1961, aged 41. *A.* 1952.
(P) HODGSON, Harold Wright. Died 13 May, 1961, aged 48. *A.* 1946.
(OF) SANE, Janardan Balkrishna, M.SC.TECH.(BOMBAY). Died 28 February, 1961, aged 61. *A.* 1945.

Erratum.—On *J.*, 184, the note on the work for which Dr G. S. Saharia was awarded the degree of D.Sc. should have referred to six- and seven-membered rings.